DEPARTMENT OF THE INTERIOR, CANADA
Hon. ARTHUR MEIGHEN, Minister; W. W. CORY, Deputy Minister
FORESTRY BRANCH—BULLETIN No. 60
R. H. CAMPBELL, Director of Forestry

CANADIAN DOUGLAS FIR

ITS MECHANICAL AND PHYSICAL PROPERTIES

Prepared under the direction of J. S. Bates, Chem. E., Ph. D.,
Superintendent of the Forest Products Laboratories
of Canada, by R. W. Sterns, B. Sc., Chief
of Division of Timber Tests

OTTAWA
J. de LABROQUERIE TACHÉ
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1918

Frontispiece.

Coast Type Douglas Fir, Vancouver Island.

DEPARTMENT OF THE INTERIOR, CANADA

Hon. ARTHUR MEIGHEN, Minister; W. W. CORY, Deputy Minister

FORESTRY BRANCH—BULLETIN No. 60

R. H. CAMPBELL, Director of Forestry

CANADIAN DOUGLAS FIR

ITS MECHANICAL AND PHYSICAL PROPERTIES

Prepared under the direction of J. S. Bates, Chem. E., Ph. D., Superintendent of the Forest Products Laboratories of Canada, by R. W. Sterns, B. Sc., Chief of Division of Timber Tests

OTTAWA

J. DE LABROQUERIE TACHÉ

PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

1918

28743—1½

TABLE OF CONTENTS

	PAGE
Introduction	7
Acknowledgments	8
Conclusions	8
Material tested	9
Results of tests	24
Number of tests made as basis for results	26
Comparison of coast and mountain types of Douglas fir	27
Variation of results	29
Comparison with results of previous investigations	29
Inter-relation of strength and density	30
Effect of moisture upon strength	32
Variation of properties with position in the tree	35
Material and methods	35
Conclusions	35
Presentation of results	36

Appendix

Outline of programme of tests	60
Mechanical tests	61
Determinations of physical and structural properties	80
Bibliography—Other publications dealing with the properties and characteristics of Douglas fir	84

CANADIAN DOUGLAS FIR

INTRODUCTION

The timber-testing programme undertaken by the Forestry Branch of the Department of the Interior at the Forest Products Laboratories of Canada is intended to include two general classes of tests:—

1. Tests of timbers of large size as used in actual construction, and containing defects such as are commonly met with in timbers of this class.
2. Tests of small specimens[1], clear, straight-grained, and free from defects.

Tests of the former type are useful for the purpose of investigating the weakening effect of the various defects which occur in timber, and for determining the efficiency of various specific grading rules in excluding such of these defects as would have a material effect upon strength, thus providing data of value in connection with the determination of suitable working stresses for various grades of timber.

Tests of the latter type afford, however, a more reasonable basis for a fair comparison of the properties of different species[2], and they have, therefore, been undertaken first, in order to provide as speedily as possible authentic data, at present entirely lacking, upon which to base comparisons of the properties of Canadian commercial timbers.

The purpose of this bulletin is to present the results of small clear specimen tests on Douglas fir (*Pseudotsuga mucronata*), the first species tested on this schedule, and also to describe the methods followed in making the various tests. These have been standardized and will be followed in making future tests on other species. The present bulletin will, therefore, be introductory to future publications which will appear from time to time as tests on other species are completed. This series of special studies was preceded by a study of structural timbers generally, embodied in Bulletin 59 of this branch and entitled "Canadian Woods for Structural Timbers."

[1] 2 by 2 inches in cross-section

[2] To obtain a fair comparison of the properties of a number of different species of timber it is essential to eliminate all extraneous factors which might have a varying effect in different cases. It is well known that the presence of knots, checks, cross-grain, and other defects decrease the strength of timber materially, but their effect is not so well understood as to be exactly calculable. Consequently corrections cannot be made on any reasonable basis for the presence of such defects in test pieces, and the only way of avoiding their effect is to use material in which they do not occur.

Absolutely clear specimens can only be obtained in small sizes in the case of many species, and the use of small specimens for any series of tests for which it is desired to have all test pieces free from defects, therefore becomes necessary.

The use of small specimens, apart from this consideration of the elimination of defects, has the further advantage of lending itself to the study of the variation of the properties of wood of different structure, as found in different portions of the same log, and in addition the obvious practical advantage that tests can be made more quickly, at less expense for material, and in greater number, thus, on averaging, minimizing the effect of errors and irreducible variables.

It should be noted that the use of specimens which do not contain defects does not imply the selection of material of unusual strength, but rather the elimination of conditions which would reduce the strength of the wood below normal.

ACKNOWLEDGMENTS

The series of tests on Canadian-grown timbers, of which the present bulletin is the presentation of the initial results[1], is modelled on a similar investigation of the properties of American timber species which the United States Forest Service has been carrying on for a number of years[2]. Special apparatus employed by the United States Forest Service in this work has been duplicated for the purpose of the present tests, and the specifications of that body have with very few exceptions been followed as closely as possible. This has been done in order that the two sets of tests might be comparable.

Acknowledgment is hereby made of detailed information kindly furnished by the officers of the United States Forest Products Laboratory, Madison, Wisconsin, regarding their apparatus and methods of testing.

The coast type Douglas fir timber tested as part basis for this report was donated by the Abbotsford Timber and Trading Company of Abbotsford, British Columbia, who bore all expenses incident to felling, yarding, loading, and preparing it for shipment.

CONCLUSIONS

Extensive tests, as described in detail in the following, on Douglas fir of the coast type and of the mountain type, from three localities in British Columbia and Alberta, point to the following conclusions:

1. Canadian-grown mountain type and coast type Douglas fir in the green condition have properties as shown in Tables 5 and 6.

2. As a result of comparisons of these figures with published results of similar tests on Douglas fir grown south of the international boundary, it appears that Douglas fir grown in Canada and that grown in the United States may be considered to be of practically identical properties.

3. Coast type Douglas fir is stronger than the mountain type of the same species. Assuming that Shipments 1 and 2 tested as the basis for this bulletin represent approximately the two extremes of development of the species, it appears that there may be variations of from 20 to 30 per cent between the average properties of material of this species grown in different localities.

4. Values for certain properties averaged for individual trees from the same locality in some cases vary by more than 30 per cent above or below the average value for five trees from that locality, but variations of more than 20 per cent above or below the average in the case of any of the more important properties are unusual.

5. Material from different positions within the same tree varies greatly in properties, the strongest and densest wood being at the periphery near the butt and the weakest at the heart of the tree. At certain sections greater variations occur from the pith to the periphery at the same height than through-

[1]For description of methods of testing see Appendix to this bulletin.

[2]Results for a large number of species have already been published. See United States Department of Agriculture, Bulletin No. 556, "Mechanical Properties of Woods grown in the United States". Washington, 1917.

out the entire length of the tree at the same distance from the periphery. Values for material from different positions within the same tree vary more than averages for different trees from the same locality.

6. Strength, density, and proportion of summer-wood in general vary in the same manner, great strength being associated with great density and high proportion of summer-wood. Weak material of low density, from the region immediately adjacent to the pith of the tree, is invariably of more rapid growth than stronger, denser wood found farther out from the heart. From these considerations it would appear that a grading rule based on density, as visually indicated by the amount of summer-wood, is a promising possibility for Douglas fir as for certain other species, and that a clause in such a rule specifying the minimum number of growth-rings per inch for material of first grade would be of value.

7. Decreasing the moisture content of Douglas fir results in greatly increasing the strength after the moisture content has been reduced below a certain value.[1] Air-drying from the green condition to a moisture content of 10 per cent, based on the weight of the dry wood, causes an increase in the strength of small clear specimens of from 20 to 200 per cent, for different strength values.

MATERIAL TESTED

The timber tested as the basis for this report comprised three distinct shipments, one of the coast type of Douglas fir, and two of the mountain type of the same species. These are as follows:—

Shipment 1.—Mountain type from Morley, Alberta[2].

Shipment 2.—Coast type from Abbotsford, British Columbia[2].

Shipment 3.—Mountain type from Golden, British Columbia[2].

Shipment 1

This shipment of mountain type Douglas fir grew on the eastern slope of the Rocky mountains on the Stony Indian reserve in the vicinity of Morley, Alberta (township 25, range 7, west of the 5th meridian). The annual rainfall at this point is in the neighbourhood of 16 inches.[3] The trees grew at altitudes ranging from 4,000 to 5,000 feet above sea level[4] on a 30 per cent to 40 per cent slope towards the northeast. The soil was clay loam, the undergrowth Douglas fir and spruce reproduction. All five trees had full crowns and branchy stems.

[1]The "fibre saturation point." This for Douglas fir is given by some authorities as 23 per cent moisture based on the dry weight of the wood. (See United States Department of Agriculture, Forest Service Bulletin 88. Cline and Knapp. "Properties and Uses of Douglas Fir." P. 54.) The results of rather incomplete tests made in this connection under the present investigation may be taken as confirming this value.

[2]The location of these points is shown on the sketch map, Fig. 20, p. 25.

[3]At Calgary, 40 miles east of Morley and at an altitude less by 640 feet, the average rainfall from 1888 to 1907 was 16·30 inches annually, according to data supplied by the Meteorological Service of Canada.

[4]In "Altitudes in the Dominion of Canada", James White, 1915 (Publication of the Commission of Conservation), the altitude of rail base at Morley Station is given as 4,078 feet above mean sea level. The collector in his notes gave the following elevations for each of the individual trees: Tree 1, 4,075 ft.; tree 2, 4,085 ft.; tree 3, 5,000 ft.; tree 4, 4,070 ft.; tree 5, 4,065 ft.

The logs when sawed at the laboratories proved to be exceedingly knotty. The dimensions of the trees as given by the collector are as follows:—

TABLE 1.—Dimensions of the Five Trees Comprising Shipment 1

Tree No.	Age.	Diameter at Breast Height. Inches.	Total Height. Feet.
1	166	18	72
2	165	17	63
3	188	15	67
4	192	18	65
5	174	15	60

Photographs of the logs of this shipment and of typical test sticks of fast, average, and slow growth, are shown in Figs. 1 to 6.

FIG. 1.—Logs of Shipment 1 at point of origin before shipment.

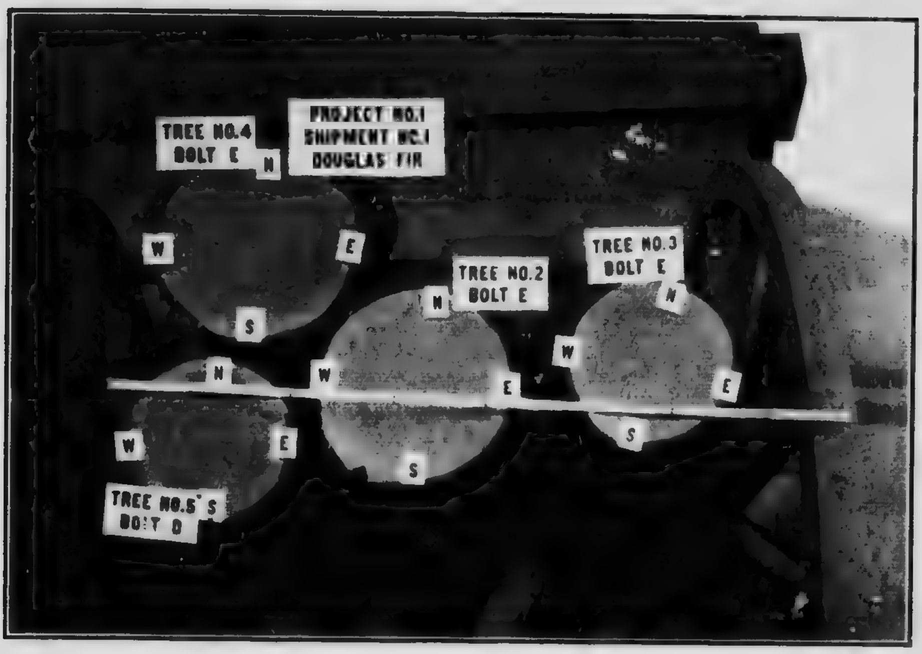


FIG. 2.—Cross-sections of Trees 2, 3, 4, and 5, Shipment 1. Trees 2, 3, and 4 at top of Bolt E, 20 feet above the stump, Tree 5 at top of Bolt D, 16 feet above the stump.

FIG. 3.—Cross-section of Tree 1, Shipment 1, at top of Bolts F and H, 24 and 32 feet above the stump. Note the closeness of the grain.

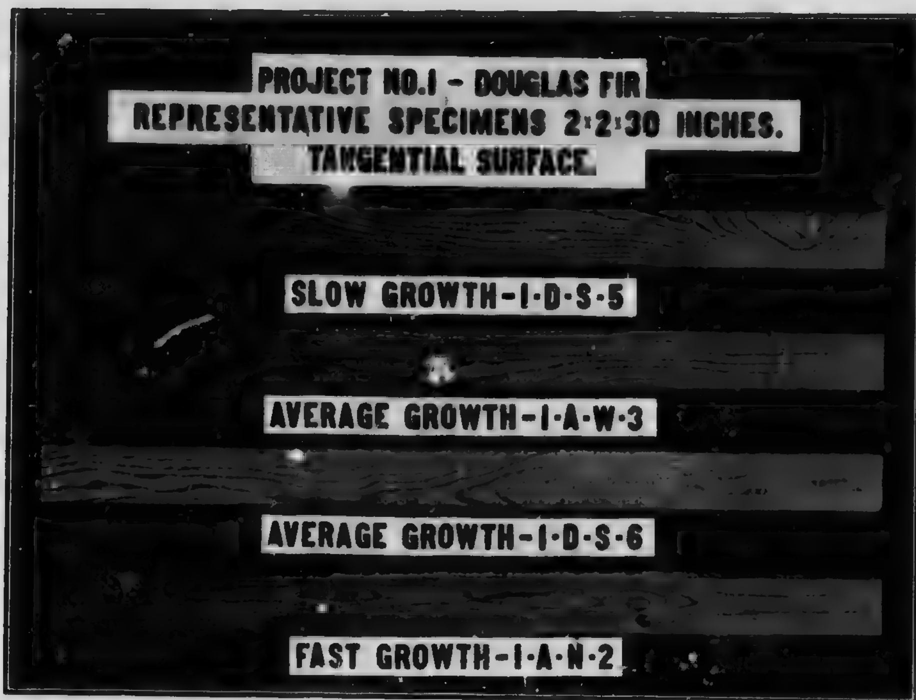


FIG. 4.—Typical specimens of Mountain Type Douglas Fir, Shipment 1, showing tangential surface of slow-, average-, and fast-growth material.

The symbols indicate shipment number, bolt number, and stick direction and number in the order of their occurrence. (See also Fig. 42 in the Appendix.)

FIG. 5.—Radial surfaces of sticks shown in Fig. 4.

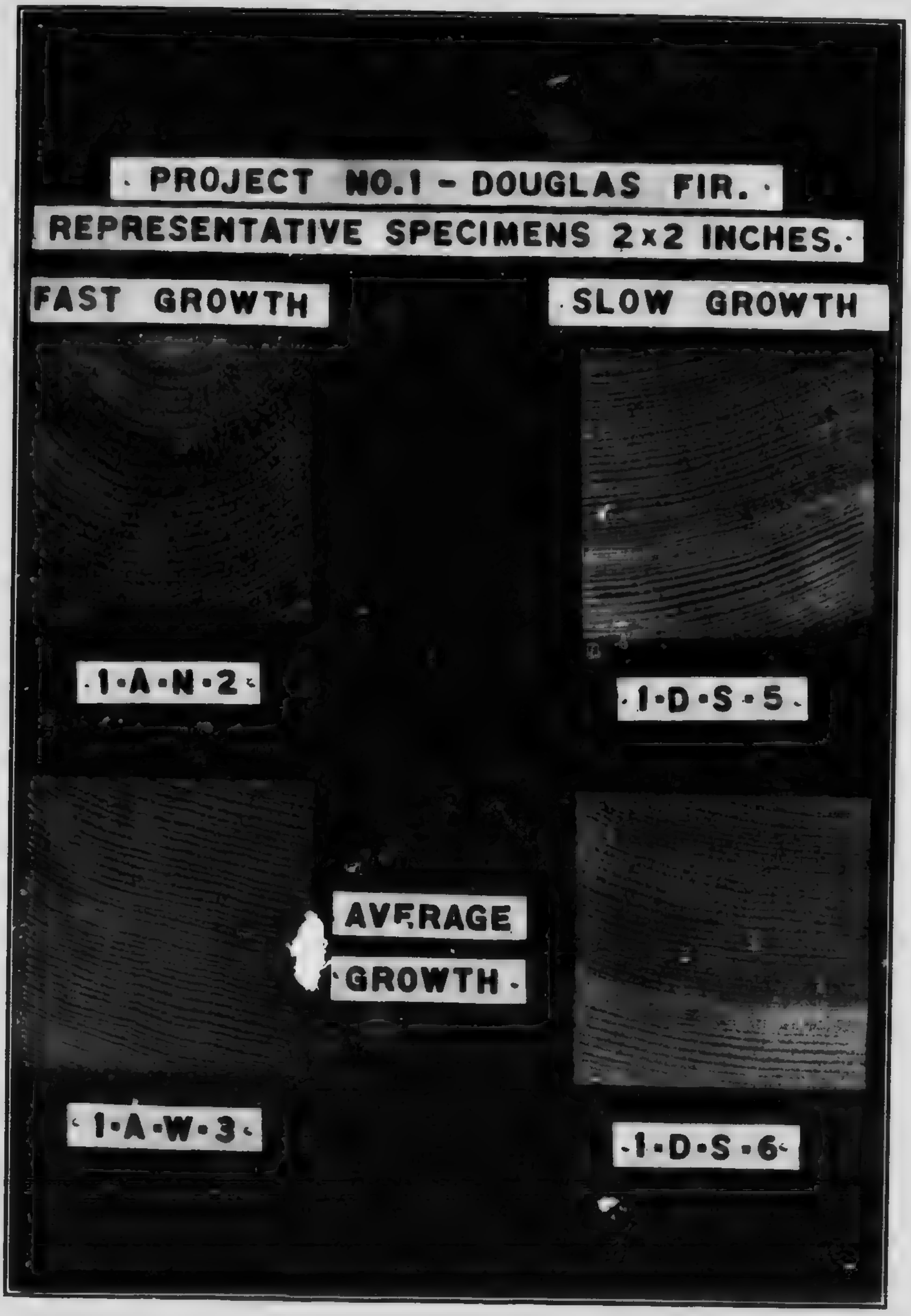


FIG. 6.—Cross-sections of sticks shown in Figs. 4 and 5.

Shipment 2

Shipment 2, coast type Douglas fir, was donated for purposes of these tests by the Abbotsford Timber and Trading Company, the timber having grown on their holdings in the southwest portion of township 16, east of the Coast meridian, close to Abbotsford, British Columbia. The trees all came from the same stand on a large flat about 100 feet above sea level.[1] The soil was a well-drained, sandy clay loam about four feet deep, underlaid with gravel. The collector refers to it as being an excellent agricultural type and notes that successful farming was carried on close to the timber. The stand was 75 per cent Douglas fir, 22 per cent western hemlock, and 3 per cent western cedar, with an undergrowth of western hemlock reproduction, ferns, devil's-club, and dense moss. The rainfall at this point is approximately 60 inches[2] annually.

The collector in his notes remarks that the trees selected belonged to a much younger class than the very large trees which are found on the coast, the latter being usually from three hundred and fifty years of age to five hundred, whereas the former were, with one exception, all under two hundred.

The dimensions of the trees were as follows:—

Table 2.—Dimensions of the Five Trees Comprising Shipment 2

Tree No.	Age.	Diameter at Breast Height. Inches.	Total Height. Feet.	Clear Length. Feet.
1	180	34.5	195	141
2	172	42	210	154
3	176	26	166	129
4	185	17	130	97
5	176	34	182	137

The logs of this shipment when sawed at the laboratory yielded a very large percentage of clear, straight-grained material. The knots were all small and occurred for the most part only at the heart of the tree.

In Figs. 7 to 13 are shown photographs of the logs of the shipment and of representative test sticks cut from them.

[1]The collector's estimate of the altitude at the point where the timber grew. Rail base at Abbotsford station is given in "Altitudes in Canada" as 88 feet above mean sea level.

[2]The average rainfall at Abbotsford from 1889 to 1904 was 60·15 inches per annum according to "The Temperature and Precipitation of British Columbia," A. J. Connor. (Publication of the Meteorological Service of Canada.)

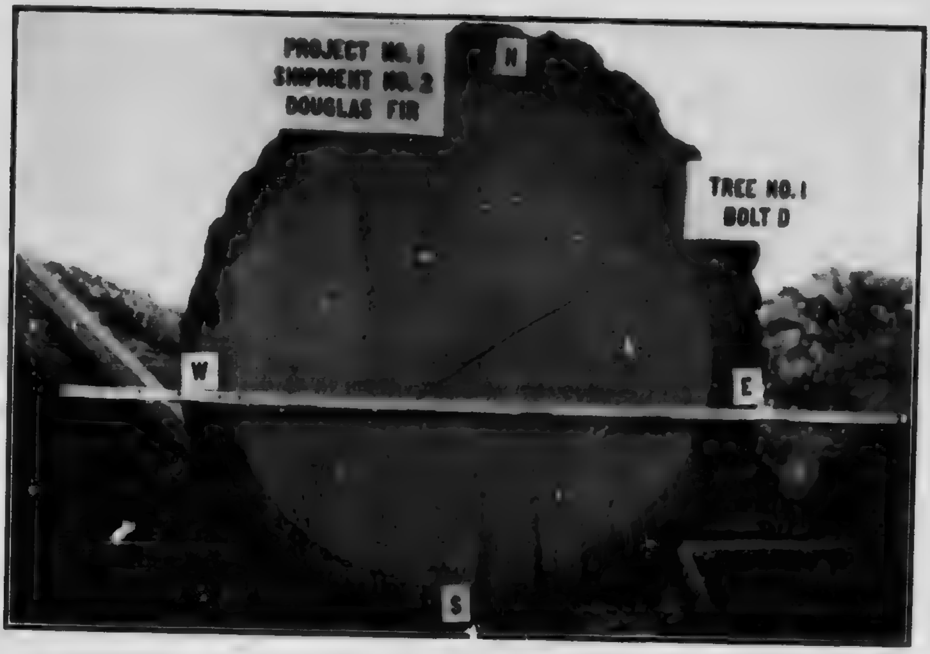


FIG. 7.—Cross-section of Tree 1, Shipment 2, at top of Bolt D, 18 feet above the ground.

FIG. 8.—Cross-section of Tree 2, Shipment 2, at top of Bolt F, 27 feet above the ground.

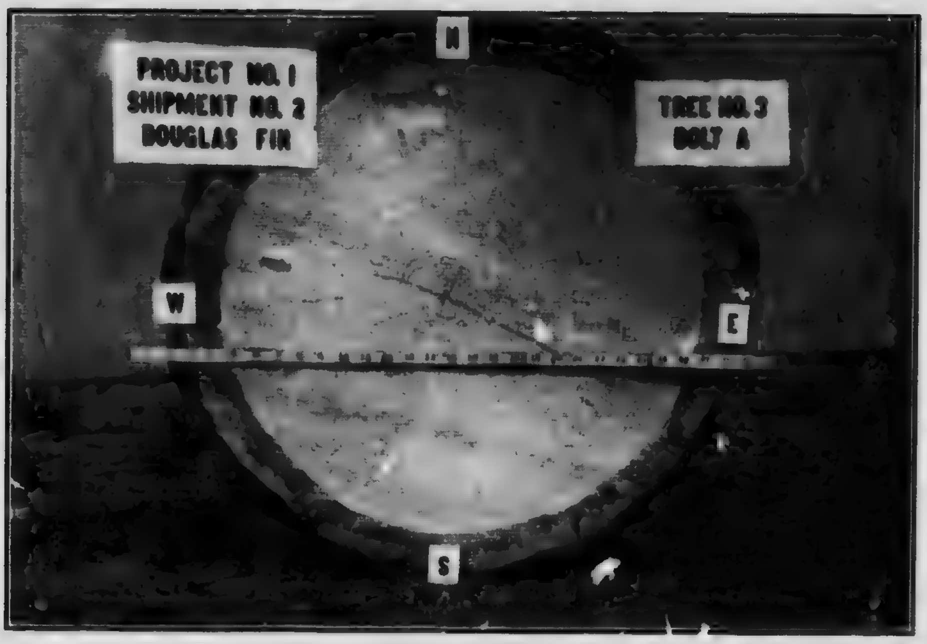


FIG. 9.—Cross-section of Tree 3, Shipment 2, at top of Bolt A, 9 feet above the ground.

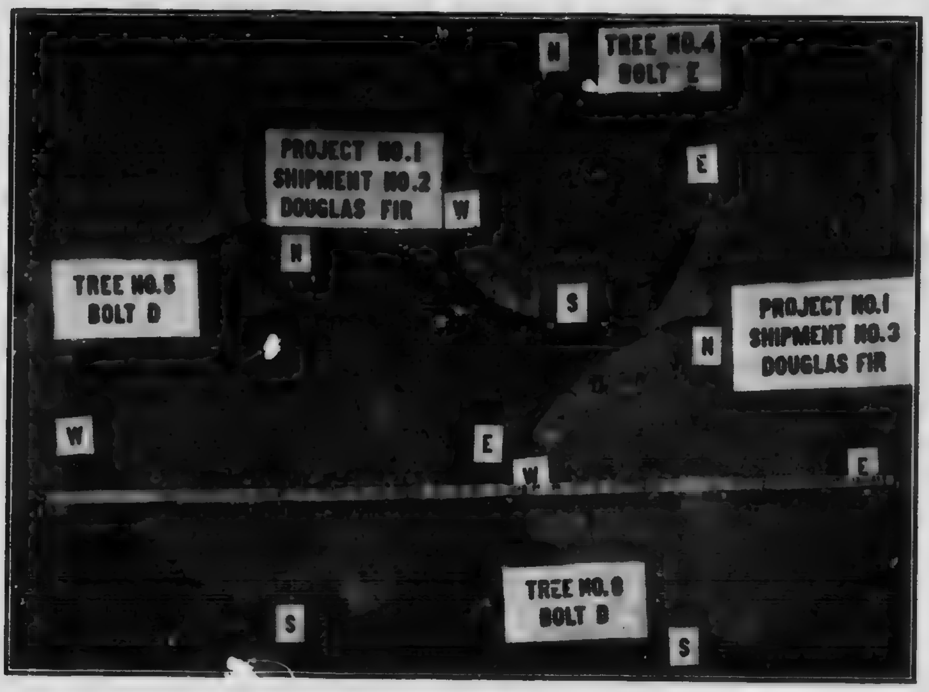


FIG. 10.—Cross-sections of Trees 4 and 5, Shipment 2, and of Tree 8, Shipment 3.
Tree 4 at top of Bolt E, 22 feet above the ground. Tree 5 at top of Bolt D, 19 feet above the ground. Tree 8 at top of Bolt D, 19 feet above the ground.

Fig. 11.—Typical Specimens of Coast Type Douglas Fir, Shipment 2, showing tangential surface of slow-, average-, and fast-growth material.

The fast-growth specimen was from the exterior of the tree and shows a width of growth-ring unusual for this position in the tree. The material of the fastest growth was usually at the centre of the tree and associated with development of less summer-wood than is seen in this particular case. (Compare Figs. 13 and 19.)

Shipment 3

Shipment 3, mountain type Douglas fir, grew on the west side of the Columbia River valley about three miles southwest of Golden, British Columbia (timber berth No. 16, township 27, range 22, west of 5th meridian).

This timber berth, in general, slopes steeply to the east but it is cut by ravines which run north and south parallel to the main Columbia valley. The soil is fairly uniform in quality, being mostly a coarse, gritty material containing a fair amount of clay. This is about twelve inches deep and is underlaid with gravel, below which, at varying distances at different points, is the bedrock which is of a schisty nature.

The stand, which was fully stocked, consisted of 80 to 85 per cent Engelmann spruce (*Picea Engelmanni*), the remainder in order of frequency being Douglas fir, western hemlock (*Tsuga heterophylla*), western cedar (*Thuja plicata*) and lodgepole pine (*Pinus Murrayana*). The undergrowth was not apparent, being covered at the time of collection by snow four to five feet deep. The collector r... that where the soil was thinnest the trees were least straight and their ...mbs most persistent. The stand had been severely burned two years

..43—2

previously and most of the specimen trees were scorched at the butt. All were, however, living when felled.

The Columbia valley in the vicinity of Golden has a comparatively dry climate, the annual precipitation being about 18 inches.[1] There is usually a heavy snowfall and a fairly long winter. Extremes of temperature occur.

The timber berth is well watered by snow-water coming down the main easterly slope of the valley from the mountains above. The secondary westerly slopes of the ravines which cut it, however, receive considerably less moisture from this source.

FIG. 12.—Radial surface of specimens shown in Fig. 11.

Tree 6 grew at an altitude of 3,600 feet above sea level on a gentle slope to the west. Trees 8 and 9 were close together at a distance of half a mile from Tree 6 and at about the same elevation. Tree 8 grew on the top of a small ridge, Tree 9 on a slight slope to the west. Trees 7 and 10 grew close to one another, about three-quarters of a mile west of Trees 8 and 9, at an altitude of about 4,000 feet[2] on a 30 per cent slope to the east.

[1]At Golden the average annual precipitation from 1902 to 1913 was 18·45 inches according to "The Temperature and Precipitation of British Columbia," A. J. Connor. (Publication of the Meteorological Service of Canada.)

[2]The site of the stand from which these trees were taken was at a considerably greater altitude than the town of Golden. Rail base at Golden station is 2,583 feet above mean sea level according to "Altitudes in Canada."

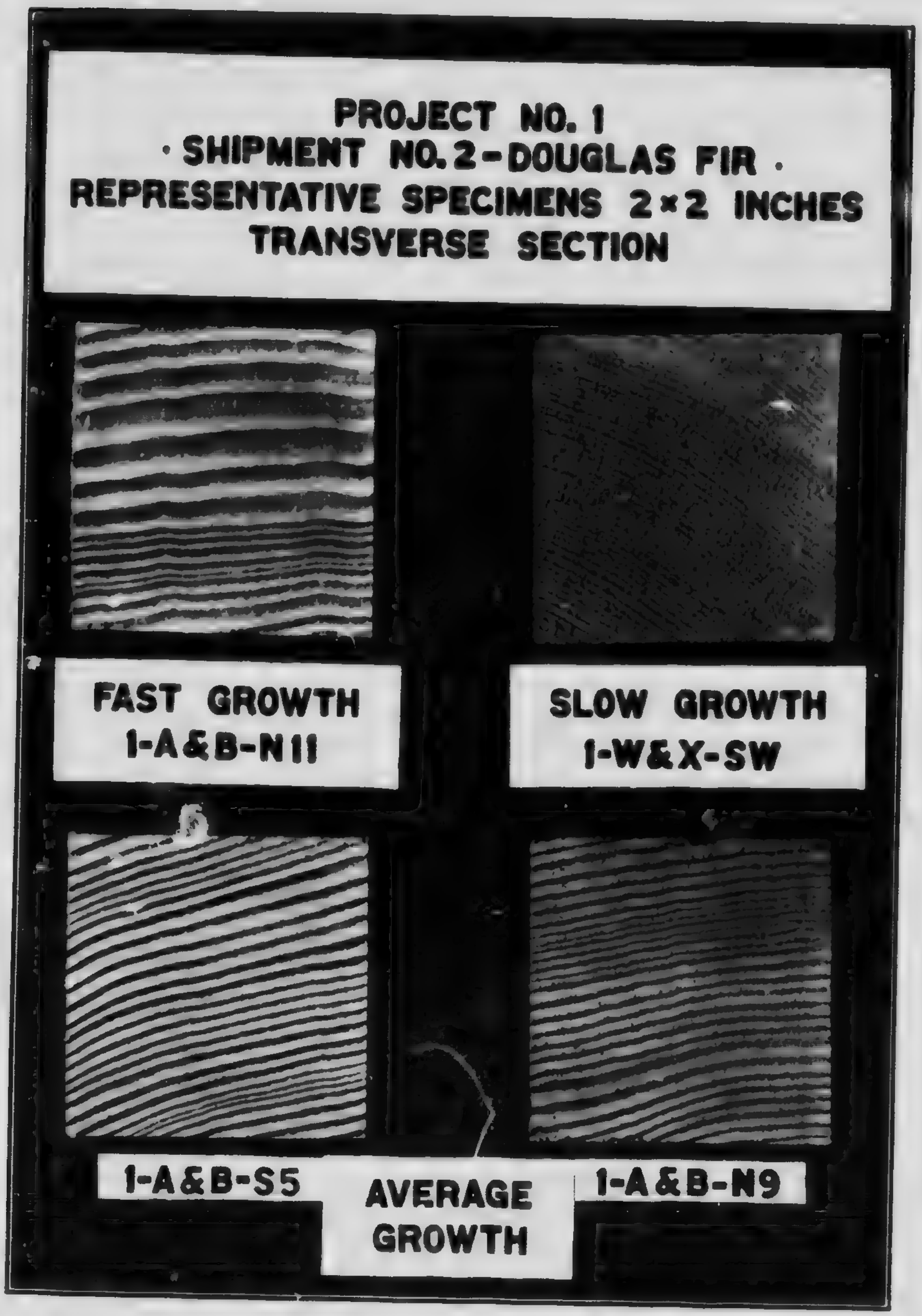


FIG. 13.—Cross-section of sticks shown in Figs. 11 and 12.

28743—2½

The dimensions of the trees as given by the collector were as follows:—

TABLE 3.—Dimensions of the Five Trees Comprising Shipment 3

Tree No.	Age. Years.	Diameter at Breast Height. Inches.	Total Height. Feet.	Clear Length. Feet.	Stump Height. Feet.
6	190–200	31	121	40	3
7	160–170	49	130	45	3
8	170–180	22	99	32	3
9	170–180	18	98	33	3
10	260–270	36	157	63	3

The logs of this shipment were of fair size and good quality, yielding a large percentage of clear material.

Photographs of log cross-sections and typical specimens of the timber of this shipment are shown in Figs. 14 to 19.

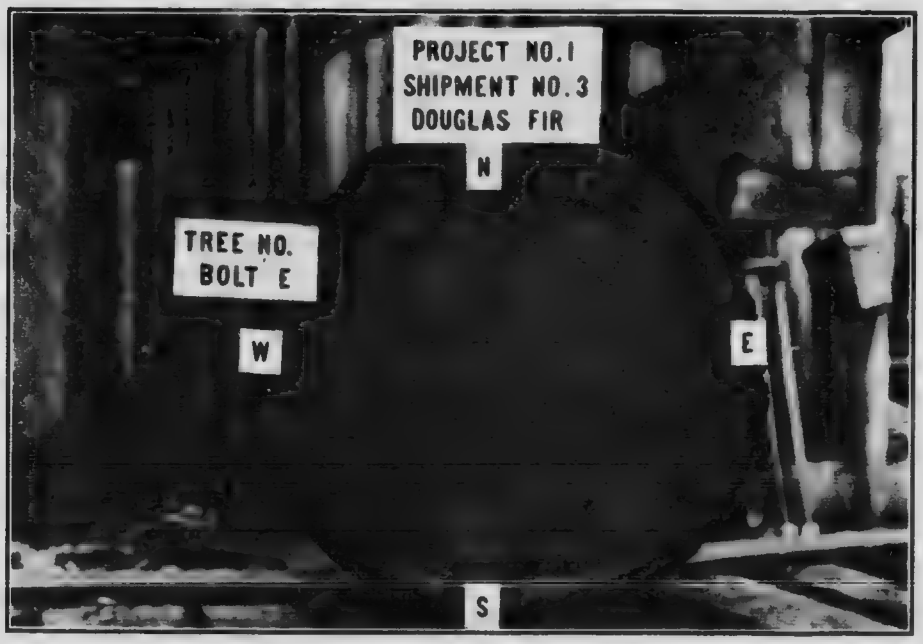


FIG. 14.—Cross-section of Tree 6, Shipment 3, at top of Bolt E, 23 feet above the ground.

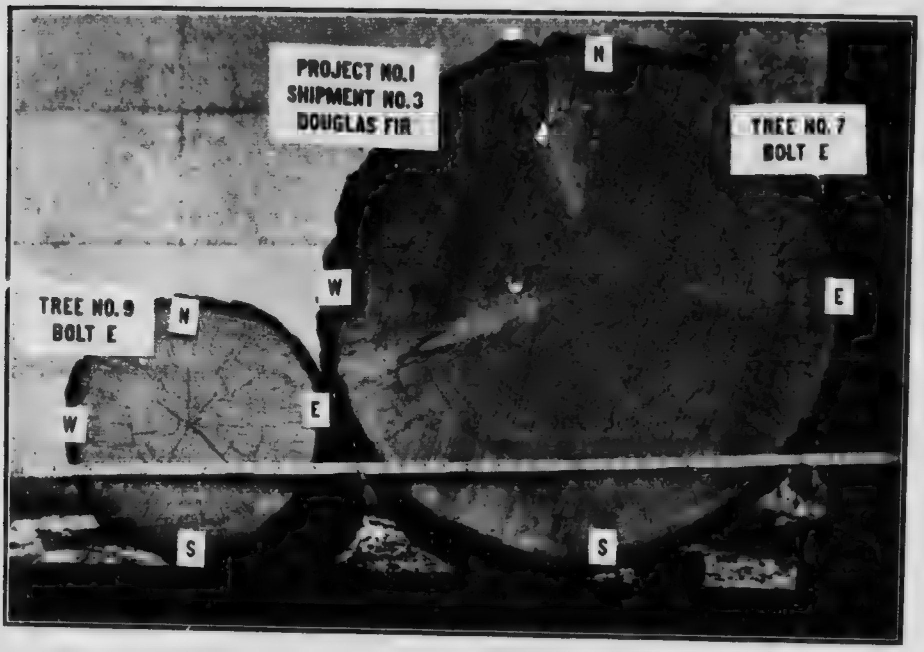


Fig. 15.—Cross-sections of Trees 7 and 9, Shipment 3, in both cases at top of Bolt E. 23 feet above the ground.

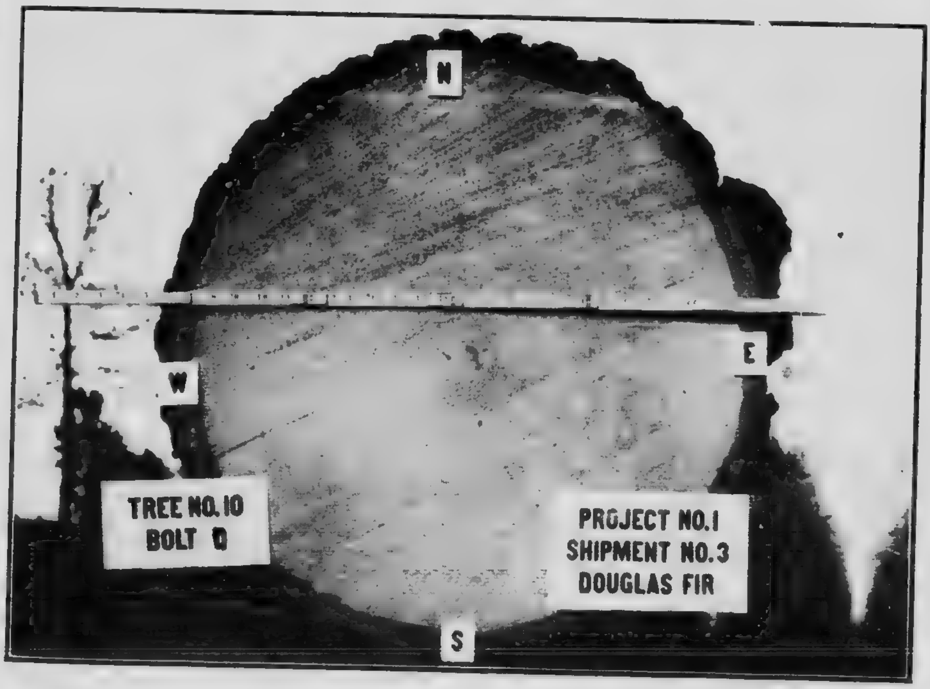


Fig. 16.—Cross-section of Tree 10, Shipment 3, at top of Bolt D, 19 feet above the ground.

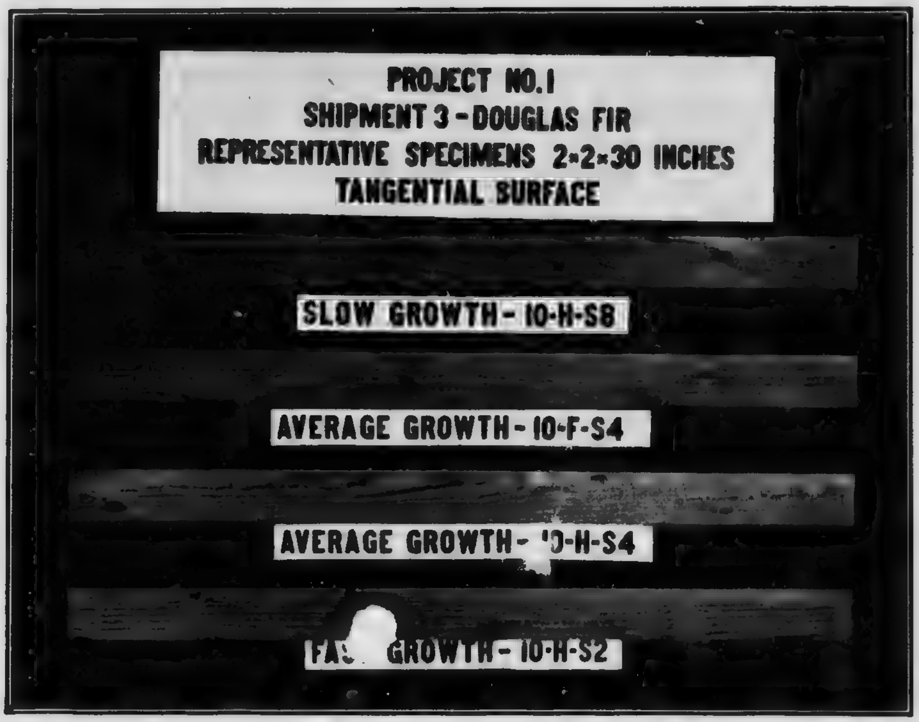


FIG. 17.—Typical specimens of Mountain Type Douglas Fir, Shipment 3, showing tangential surface of slow-, average-, and fast-growth material.

FIG. 18.—Radial surfaces of specimens shown in Fig. 17.

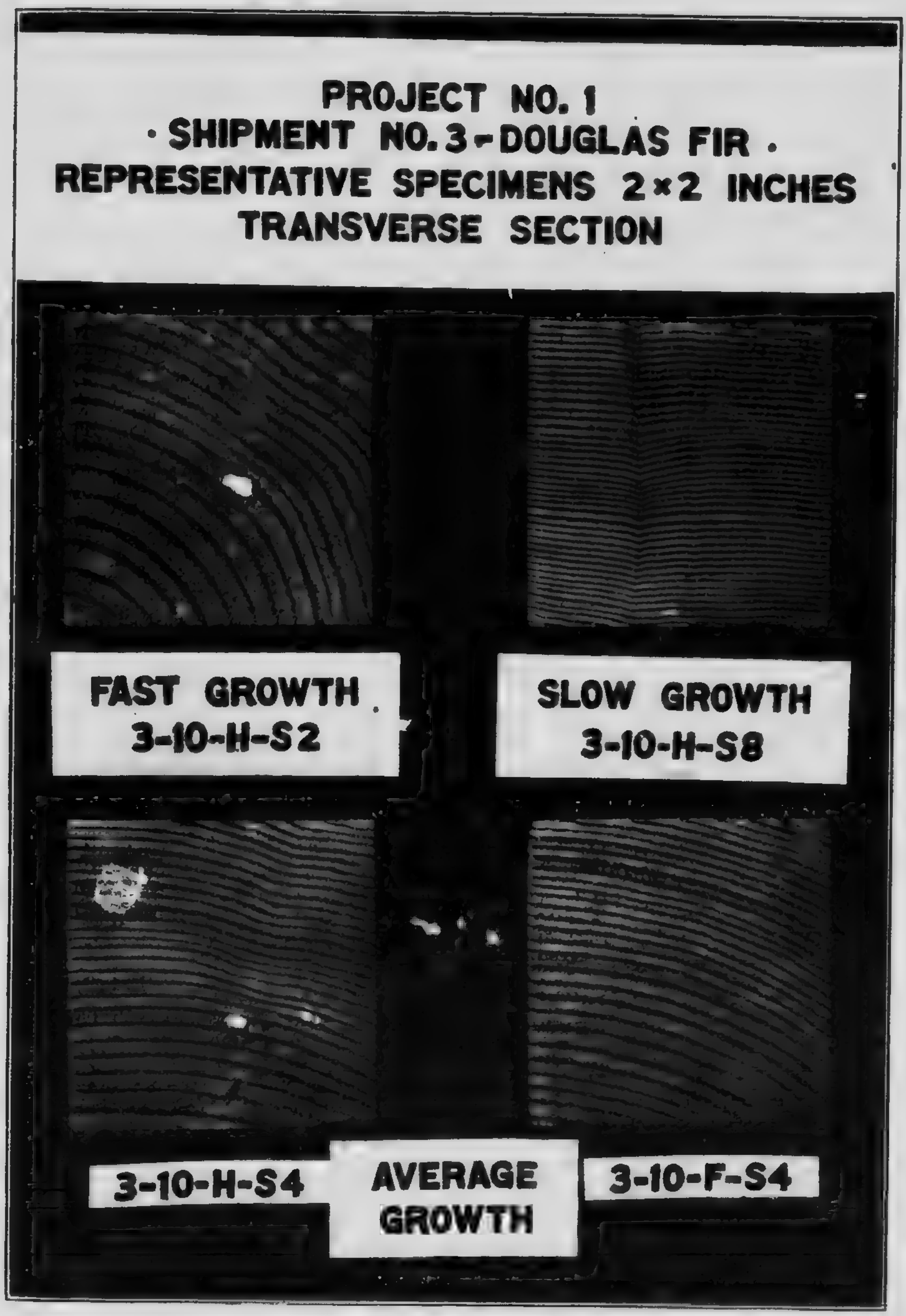


FIG. 19.—Cross-sections of specimens shown in Figs. 17 and 18.

The sketch map, Fig. 20, shows the general relative location of the sites upon which the three shipments grew. It will be seen that Shipment 2 was from the Coast region not far from the international boundary line. Of Shipments 1 and 3, the former from Morley, Alberta, was from the Atlantic slope of the continental divide, the latter from Golden, British Columbia, from the Pacific slope. Both grew at approximately the same altitude (4,000 ft.), but Shipment 3, from Golden, British Columbia, which comprised much better developed trees than Shipment 1 was from a site rather better watered than that upon which the latter shipment grew.

The following Table (4) shows the comparative ranges of temperature, altitudes, and rainfalls at the three localities in question:—

TABLE 4.—Ranges of Temperature, Altitudes, and Annual Precipitations at Sites of Shipments 1, 2, and 3

Ship. No.	Locality.	Altitude. Feet above mean sea level.	Average annual Precipitation. Inches.*	Mean Temperatures.*		
				Summer.	Winter.	Annual.
1	Morley, Alberta............	4,000	16	58	15	37
2	Abbotsford, British Columbia	100	60	61	35	48
3	Golden, British Columbia....	4,000	18	59	15	39

*Figures supplied by the Meteorological Service of Canada.

RESULTS OF TESTS

Strength tests and determinations of physical properties made upon small clear specimens of the material of the three shipments of Douglas fir, described in the preceding section, gave results as shown in Tables 5, 6, and 8. Table 6, opp. p. 32, gives complete results for all the various types of test[1] with averages for the three shipments, and for the individual trees of each shipment. Table 5, p. 26, gives averages for the three shipments, for the more important tests, in a form more convenient for reference. Table 8, opp. p. 32, shows maxima and minima tree and individual test values for the three shipments, together with the variations of these values from the shipment averages, expressed as percentages of the shipment averages.

[1]A full description of the methods employed in making these tests will be found in the Appendix to this bulletin, p. 60.

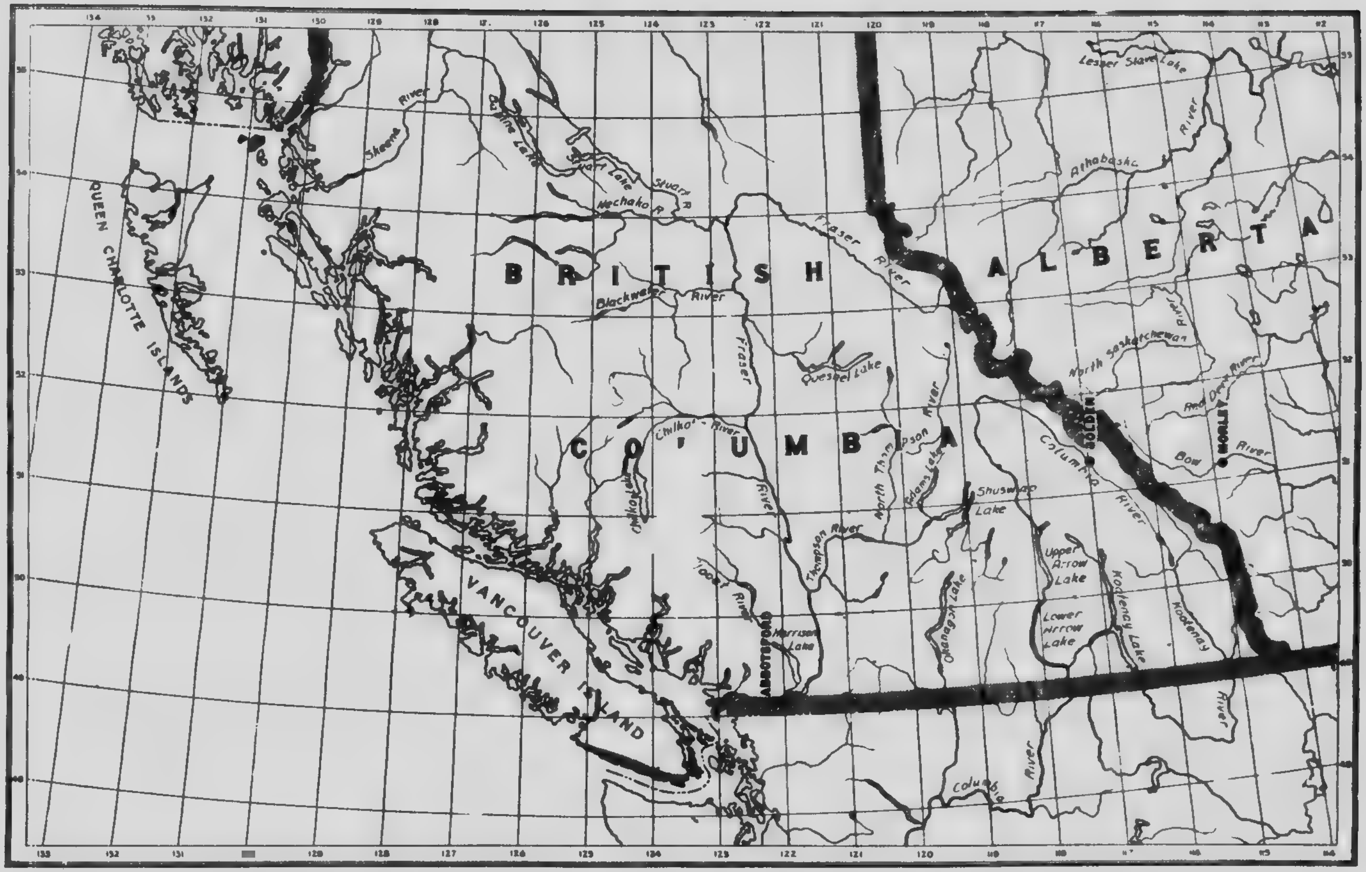


FIG. 20.—Sketch map showing location of sites of three shipments of Douglas fir tested as basis for this report.

TABLE 5.—Results of Tests on Small, Clear Specimens of Green Douglas Fir (Coast and Mountain types) from three Localities in Alberta and British Columbia.

(All stresses expressed in pounds per sq. inch.)

	Shipment 1 Mountain fir from Morley, Alta.	Shipment 3 Mountain fir from Golden, B.C.	Shipment 2 Coast fir from Abbotsford, B.C.
Bending (Static)—			
Fibre stress at elastic limit	3,880	4,390	5,210
Modulus of rupture	6,770	7,530	8,180
Modulus of elasticity	1,232,000	1,488,000	1,736,000
Compression Parallel to Grain—			
Compressive stress at elastic limit	2,800	2,510	3,430
Crushing strength at maximum load	2,960	3,380	4,010
Compression Perpendicular to Grain—			
Compressive stress at elastic limit	457	495	535
Shearing—			
Shearing strength parallel to grain	837	900	906
Weight per cu. ft. (lbs.) oven-dry (based on green volume)	26.3	27.5	27.6
Specific gravity (based on volume green and weight oven-dry)	0.421	0.441	0.443

NUMBER OF TESTS MADE AS BASIS FOR RESULTS

The total number of tests upon which the figures given in Table 5 and Table 6 are based, are as given in the following Table (7):—

TABLE 7.—Total Number of Tests made as the Basis for Figures given in Tables 5 and 6.[1]

Shipment No.	Locality.	Static Bending.	Impact Bending.	Compression Parallel to grain.	Compression Perpendicular to grain.	Hardness.	Shearing Parallel to grain.	Cleavage.	Tension Perpendicular to grain.	Volumetric Shrinkage.	Linear Shrinkage.	Total.
1	Morley, Alta	26	9	51	33	25	.	43	42	8	25	306
2	Abbotsford, B.C.	68	27	150	44	45	36	34	36	21	24	485
3	Golden, B.C.	44	21	105	45	41	34	32	34	18	22	396
	Total	138	57	306	122	111	114	109	112	47	71	1,187

The number of test pieces from each tree naturally varied considerably depending upon the size of the tree. The standard numbers of tests of each type for each tree, as specified in the working plan in accordance with which the tests were made, are given in detail in the Appendix, p. 60.

[1]In addition to these, 2,912 similar tests were made in an investigation of the variation of properties throughout one complete tree. See p. 35.

This specification was followed as closely as possible, but occasionally, more particularly in the case of Shipment 1, the logs of which were all rather small and exceedingly knotty, it was impossible to obtain clear material sufficient for the full number of tests. As a consequence in a number of instances figures given in Tables 6 and 8 as averages for an entire tree are based on a single test only. As will be seen from data presented elsewhere in this bulletin, Douglas fir varies greatly in properties from point to point in the cross-section of the tree, and individual tests may, therefore, give results differing widely, depending on the position of the specimen tested relative to the heart of the tree. The figures mentioned may not be, for this reason, accurately representative of average properties, although in every case in which this condition occurred the log in question was quite small and variations in properties throughout the cross-section would not be therefore, so great as would otherwise be the case. All figures which in this way are the result of only one test have, in any case, been indicated on Tables 6 and 8, and due allowance can be made for this condition when considering the results. All figures not so indicated are based on an adequate number of tests.

Comparison of Coast and Mountain Types of Douglas Fir

As will be seen from Tables 5 and 6 the three shipments Douglas fir tested were in the following order (ascending) as regards average strength and density:

1. Mountain type Douglas fir from Morley, Alberta, Shipment 1.
2. Mountain type Douglas fir from Golden, British Columbia, Shipment 3.
3. Coast type Douglas fir from Abbotsford, British Columbia, Shipment 2.

The shipment of coast type fir was stronger than either of the two shipments of mountain type fir, and of the latter that from the western slope of the continental divide was stronger than that from the eastern slope.

It is worthy of note that the strongest material came from the region of greatest annual precipitation and greatest mean annual temperature, and that, of the other two shipments, the weaker was from the region of least annual precipitation and lowest annual mean temperature. The trees comprising the strongest shipment also were larger in proportion to age than those of the other two shipments, and the trees of the weakest shipment were the smallest. This would seem to indicate that Douglas fir trees grown in an environment favouring the most vigorous development may be expected to produce the strongest and densest timber.

It is probable that the distinction between the so-called " mountain " and " coast " Douglas fir is largely a matter of locality,[1] and that it would be possible to find material of characteristics ranging everywhere between the extremes of development of the two types. This is illustrated by the fact that the shipment of mountain fir from Golden, British Columbia, is of properties about midway between those of the other two shipments, which are probably approximately representative of the extremes of development of the species.

[1]Botanists while noting a difference between Douglas fir grown in the mountains and that occurring on the coast give both the same scientific name, *Pseudotsuga mucronata*.

The collector notes the occurrence in another locality of mountain type Douglas fir of characteristics even more closely approaching those of the coast fir than the Golden shipment.

The Douglas fir at present being exported from British Columbia is probably largely of the coast type. It is estimated that the total quantity of this species sawn in Canada during the year 1915 was 400,273,000 feet board measure, and that of this fully 86 per cent should be classed as coast type Douglas fir.

While averages for the three shipments were in the above order of magnitude for all strength values, with but very few exceptions, the individual trees of each of the shipments varied considerably in properties from the averages, certain of the trees of the shipment of intermediate properties (Shipment 3, mountain type fir from Golden, British Columbia) being stronger than the weaker trees of the strongest shipment, and certain others weaker than the stronger trees of the weakest shipment. In all the more important tests, however, the weakest tree of the strongest shipment (coast type fir) was stronger than the strongest of the weakest shipment (Shipment 1—mountain type fir from Alberta).

Exceptions to the above order of magnitude for the three shipments as regards average strength values occur in the following tests:

1. Cleavage,
2. Tension perpendicular to grain,
3. Work to maximum load in static bending,
4. Compressive stress at elastic limit in compression parallel to grain,
5. Work to elastic limit in impact bending,
6. Tangential hardness,
7. Radial shear.

Considering these in order in the case of items 1, 2, and 3 the usual order of strength is consistently reversed, the mountain type fir from Alberta having the greatest strength and the coast type fir the least. The variations also are considerable in amount. The reason for this condition is not understood.

In the case of item 4, compressive stress at elastic limit, the shipment of mountain type fir from Alberta is stronger than that from Golden, British Columbia, although both are weaker than the coast type fir shipment. The explanation of this is probably that the value for the Alberta fir is unduly high. Less sensitive compressometers than those used in testing the other two shipments were employed in the case of this shipment, and the load-compression curves obtained were for this reason less accurate. The elastic limit point would as a consequence appear to occur at a higher value of the load than was actually the case.

In items 5, 6, and 7 the values for the British Columbia mountain type fir are greater than those for the coast type fir, although the latter is considerably stronger than the Alberta shipment of mountain type fir. The discrepancies are, however, all slight in amount and may be due to failure to obtain strictly comparable test pieces from each of the three shipments. (They occur in tests of which a relatively small number are made.)

Variation of Results

The amounts of variations in the average strength values for the three shipments are indicated in Table 6. Assuming that the coast type fir shipment from Abbotsford, British Columbia, and the mountain type fir from Morley, Alberta, are approximately representative of the two extremes of development of Douglas fir[1] it appears that there may be variations of from 20 to 30 per cent between the average properties of material of this species grown in different localities.

The amounts of variation of maxima and minima tree averages and individual test values above or below the average for the entire shipment, for each of the three shipments, are shown in Table 8.

It will be seen that the trees of Shipment 3—mountain type fir from Golden, British Columbia—showed a wider variation in properties than those of either of the other two shipments. Variations of tree averages from shipment averages in few instances ran as high as 40 per cent, but variations from the average of 20 per cent in the case of any of the more important strength values were rare.

Variations of individual test values from the shipment averages were, as would be expected, considerably greater than the variations of the tree averages, in a few cases being as great as 70 per cent.

Comparison with Results of Previous Investigations

A comparison of the above figures with the results of similar tests made by the United States Forest Service on Douglas fir shows that, in general, the results check rather closely. The shipment of mountain type fir from Morley proves to be of almost identical average properties with a similar shipment of mountain type fir from Montana and Wyoming,* figures for which are given in

*The close agreement of the figures will be seen from the following table which shows the variation of the more important strength values for the Alberta Douglas fir above or below the corresponding values for the Montana and Wyoming Douglas fir.

	Variation of Alberta Douglas Fir above or below corresponding value for Montana and Wyoming Douglas Fir. Per cent of Alberta Fir.
Static bending.—Fibre stress at elastic limit	+7·2
" Modulus of rupture	+5·5
" Modulus of elasticity	+4·2
Compression parallel to grain—Maximum crushing strength	-1·4
Compression perpendicular to grain—Compressive stress at elastic limit	+1·5
Shearing strength parallel to grain	−5·1
Specific gravity	+5·0

a table in United States Department of Agriculture, Bulletin 556. Similarly the strength values obtained for the shipment of coast type fir from Abbots-

[1]The trees from which the coast type Douglas fir was cut "were all of a much younger class," to quote the collector, "than the very large trees which are found on the coast," the latter being "usually from three hundred and fifty years of age to five hundred, whereas the trees selected were under two hundred." As is shown elsewhere in this bulletin strength increases with distance from the heart in such trees and it is, therefore, very probable that more mature trees of coast type fir would have given somewhat higher strength values than those tested.

ford, British Columbia, agree very closely with the results of tests on Douglas fir from Washington and Oregon, as reported in the same publication.*

*The variations for the more important properties of these two shipments are indicated in the following table.

	Variation of B.C. Douglas Fir above or below corresponding value for Washington and Oregon Douglas Fir. Per cent of B.C. Douglas Fir.
Static bending.—Fibre stress at elastic limit	+ 4·0
" Modulus of rupture	+ 4·6
" Modulus of elasticity	+ 9·0
Compression parallel to grain—Maximum crushing strength	+ 1·7
Compression perpendicular to grain—Compressive stress at elastic limit	+ 0·9
Shearing strength parallel to grain	− 0·4
Specific gravity	− 1·6

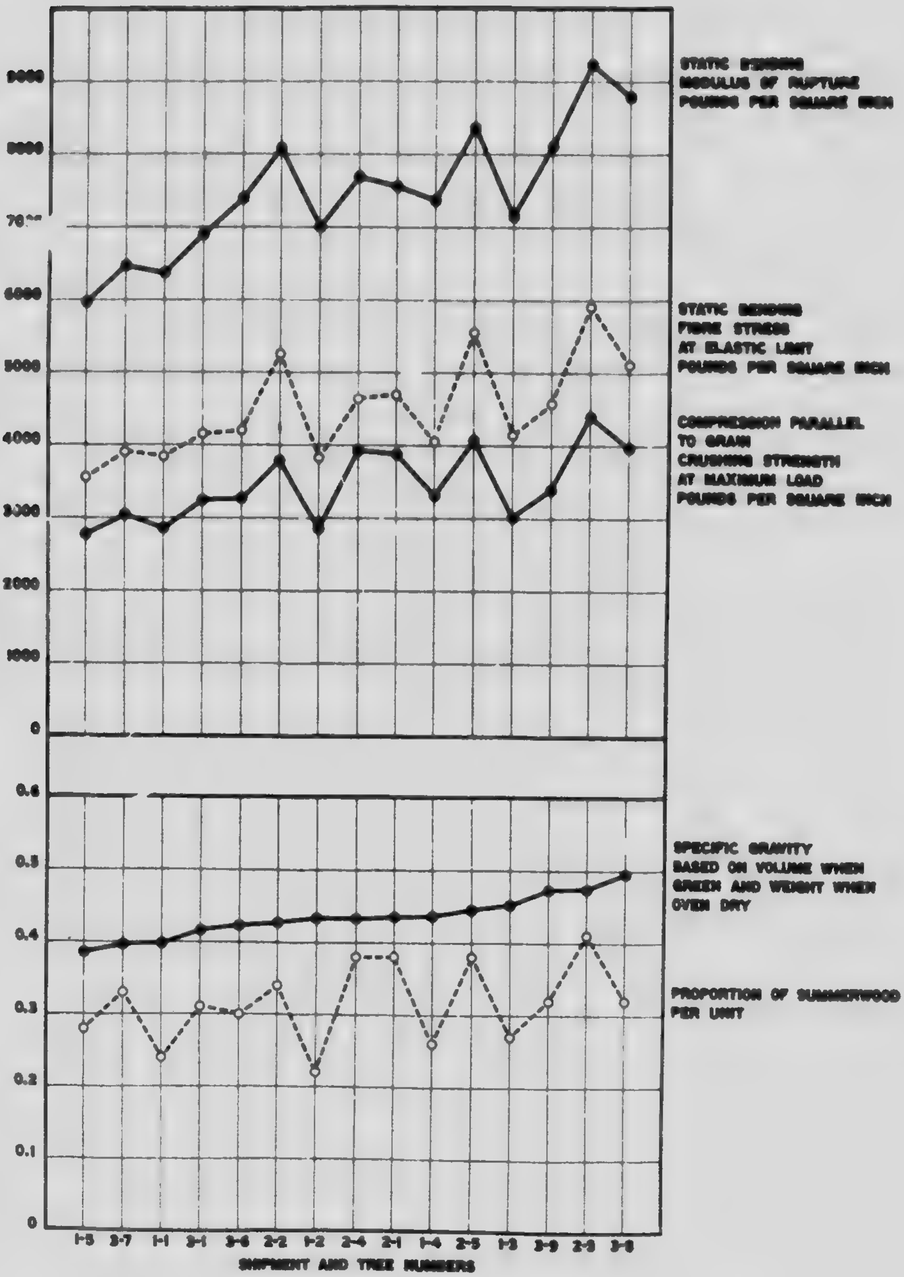
On the basis of these tests it is probably a reasonable conclusion that Canadian-grown and American-grown Douglas fir may be considered to be of practically identical properties.

Inter-relation of Strength and Density

It has been shown by various investigators that a relation exists between the strength of wood and its density, dense wood being stronger than less dense wood of the same species, and of two different species the heavier being as a rule the stronger. This rule, of course, applies only in the case of comparisons on the basis of the inherent density of the wood substance itself. Timbers heavy by reason of the presence in the wood of extraneous substances such as moisture, oils, resins, etc., would not necessarily be stronger than other lighter timbers in which these substances were present in lesser amounts. Douglas fir and longleaf pine are two species which illustrate rather well this consideration. The latter timber is considerably heavier than Douglas fir by reason, in part, of a higher resin content but is not proportionately stronger, Douglas fir being in some respects the stronger of the two timbers.

This relationship of strength and density proves to be so consistent and characteristic that it has been made the basis for a successful grading rule for strength in the case of the southern pines, the proportion of summer-wood being used as a visual index of the density. Each growth-ring, as seen in the cross-section of a piece of wood of longleaf pine or Douglas fir, consists of a band of light coloured wood on the inside, which merges into a darker coloured band of harder material on the outside of the ring. The light coloured wood which is formed during the early part of the growing season is known as " spring " or " early " wood, the dark coloured portion formed during the late summer and fall is referred to as " summer " or " late " wood. Summer-wood is several times heavier than spring-wood, and correspondingly stronger, and a timber containing a large proportion of summer-wood will, accordingly, be of greater strength than one in which less summer-wood appears.

Reference to the tables of results presented in this bulletin shows that this principle is confirmed by the tests t present under consideration. In Table 6



RELATION OF MECHANICAL PROPERTIES TO DENSITY.

FIG. 21.—Curves show:.g parallel variations of average strength, density, and proportion of summer-wood for fifteen trees of Douglas fir. (Shipments 1, 2 and 3.)

it will be seen that the average figures for specific gravity and percentage of summer-wood for the three shipments are in the same order of magnitude as the large majority of the strength values, the shipment of coast type Douglas fir, which is the strongest of the three, being the most dense and having the highest percentage of summer-wood, and the mountain type Douglas fir from Alberta, which is the weakest, being the least dense and having the lowest proportion of summer-wood. The variation in the mechanical properties is, however, proportionately much greater than the corresponding variation in specific gravity.

The average values for the individual trees of the three shipments while not conforming to this rule with absolute regularity nevertheless show that wood of great density and high proportion of summer-wood tends to be stronger than less dense material of lower proportion of summer-wood. This is illustrated by Fig. 21, which shows parallel curves of strength, density, and percentage of summer-wood for each of the fifteen trees tested, arranged in ascending order of density as indicated by specific gravity. It will be observed that the other curves while rather irregular nevertheless also have an upward trend in the same direction.

Diagrams plotted to show the variation of properties throughout all parts of a single tree (Figs. 23 to 41), also show a parallelism of the curves of strength, density, and proportion of summer-wood, indicating that in all portions of this tree great strength was associated with great density and high proportion of summer-wood.

It would appear that a grading rule for Douglas fir based on density as indicated by proportion of summer-wood, similar to that at present in use for southern pine, would be a promising possibility.

Effect of Moisture upon Strength

Tests to investigate the effect of air-drying upon strength made on special material from each of the above three shipments indicate that a very considerable increase in strength results from air-drying, the increase, however, only taking place below a certain critical moisture content.[1] Two contiguous four-foot bolts were cut from one[2] of the five trees tested as basis for the average for green material for each of the three shipments. These logs were sawed into sticks in the usual manner[3] and half the sticks of each interchanged, so forming two " composite " bolts which should be of practically identical properties as far as variation with height in the tree is concerned. One of the " composite " bolts was tested in the green condition, the other was air-dried to constant weight and tested. The ratios of the average strength values for the air-dry bolt to those for the green bolt are a measure of the effect of the air-drying upon strength. These ratios for all three shipments, expressed as percentages, are shown in Table 9 (following).

[1]The so-called "fibre saturation point." See U. S. Forest Service Bulletin No 70. H. D. Tiemann "Effect of moisture upon the strength and stiffness of wood." pp. 82-84

[2]In the case of Shipment 1, the trees being small, material was taken from each of two trees.

[3]See Appendix, Fig. 42.

rentage of
gnitude as
e Douglas
aving the
fir from
ite west
perties is,
riation in

nts while
how that
stronger
llustrated
entage of
ing order
the other
d in the

all parts
strength,
s of this
ortion of

ersity as
use for

special
iderable
taking
our-foot
age for
red into
forming
rties as
posite"
onstant
air-dry
g upon
es, are

ing small,

TABLE 6.—RESULTS OF TESTS ON SMALL CLEAR SPECIMENS—GREEN DOUGLAS FIR (COAST

AVERAGES FOR THE THREE SHIPMENTS AND FO

Shipment No.	Log No.	Bolt No.			Moisture content based on weight of wood when oven-dry	Specific gravity based on weight when oven-dry and on volume when tested	Specific gravity based on weight when oven-dry and on volume when oven-dry	Fibre stress at elastic limit per square inch	Modulus of rupture per square inch	Modulus of elasticity per square inch	Work in bending per cubic inch of specimen: To elastic limit	To maximum load	Total	Fibre stress at elastic limit per square inch
					Per cent			Pounds	Pounds	1,000 pounds	Inch pounds	Inch pounds	Inch pounds	Pounds
1	1	D		4	34.4	0.398	0.430	3,837	6,367	[illegible]	.65	5.5	11.4	5,633
		C & D			34.4	0.433	0.467	3,827	6,998	[illegible]	.69	9.0	15.5*	6,900*
		C & D			[illegible]	0.452	0.49[illegible]	4,141	7,143	[illegible]	.70	8.9	11.8*	8,590*
	4	I			[illegible]	0.436	0.483	4,057	7,363	[illegible]		7.8	11.7*	7,160*
		D			[illegible]	0.385	0.419	3,550*	5,960*	[illegible]*	.72*	7.0*		6,455
1	**Average.**		26.2	25	**34.7**	**0.421**	**0.458**	**3,880**	**6,770**	**1,232**	**0.69**	**7.6**	**12.6**	**6,950**
		D & I			[illegible]	0.473	0.471	4,205	7,398	[illegible]	.65	7.0	14.9	7,892
		I			[illegible]	0.396	0.428	3,903	6,467	[illegible]	.71	6.0	10.6	7,268
		D			[illegible]	0.495	0.549	5,109	8,784	[illegible]	.95	8.3	19.2	10,040
		I			[illegible]	0.478	0.525	4,580	8,110	[illegible]	.70	7.4		8,810
		D			[illegible]	0.416	0.44	4,151	6,898	[illegible]	.68	5.6	15.1	7,567
3	**Average.**		17.4	32	**33.0**	**0.441**	**0.483**	**4,390**	**7,530**	**1,488**	**0.74**	**6.9**	**14.9**	**8,320**
		D			[illegible]	0.433	0.508	4,695	7,556	[illegible]		6.7	16.5	9,117
		I & I			[illegible]	[illegible]	0.456	5,251	[illegible]	[illegible]		7.6	18.3	[illegible]
		A			[illegible]	[illegible]	0.490	5,907	[illegible]	[illegible]		6.9	19.1	8,798
		I			[illegible]	[illegible]	[illegible]	4,642	7,690	[illegible]	[illegible]	4.6		
		D			[illegible]	0.448	0.496	[illegible]	[illegible]	[illegible]	[illegible]	6.9	19.8	8,990
2	**Average.**		13.[illegible]	38	**31.7**	**0.443**	**0.488**	**5,210**	**8,180**	**1,750**	**0.88**	**6.5**	**18.4**	**8,940**

RATIOS AND VARIATION

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	116.9	68.5	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	106.[illegible]	81.0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	101.6	101.0	101.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.5	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19.0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0

R COAST AND MOUNTAIN VARIETIES; FROM [illegible] LOCALITIES IN ALBERTA AND BRITISH COLUMBIA
S AND FOR THE INDIVIDUAL TREES OF EACH SP[illegible]

Fibre stress at elastic limit per square inch	Modulus of elasticity, per square inch	Work in bending to elastic limit, per cubic inch of specimen	Height of drop of 51.75 lb hammer causing complete failure of specimen	Compressive stress at elastic limit per square inch	[illegible]	M[illegible]	Compressive stress at elastic limit per square inch (compression perpendicular to grain)	Hardness: Radial surface	Hardness: Tangential surface	Hardness: End surface	R[illegible]	[illegible]	Splitting: Radial	Splitting: Tangential	[illegible]	[illegible]	[illegible]	Shrinkage: Radial	Shrinkage: Tangential
Pounds	1,000 pounds	Inch pounds.	Inches.	Pounds	[illegible]	[illegible]	Pounds	Pounds	Pounds	Pounds	P[illegible]	[illegible]	Pounds	[illegible]	[illegible]	[illegible]	[illegible]	Per cent	Per cent
5,633	1 313	1 35	13	2 608		[illegible]	402	412	[illegible]	475		[illegible]	255*	[illegible]		[illegible]	10 9	3 9	7 5
6,900*	1 407*	1 [illegible]	12*	2,789		[illegible]	457	453	436	528	[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6 6
8 590*	1 433*	2 [illegible]	29*	2,955*		1 [illegible]41*	[illegible]	449	431	[illegible]	[illegible]	[illegible]	225	[illegible]	[illegible]	[illegible]	[illegible]	4 [illegible]	[illegible]
7 160*	1,448*	1 97*	17*	3,154		1 468	492	438	447	486	[illegible]	[illegible]	223*	[illegible]	[illegible]	[illegible]	[illegible]	4 [illegible]	[illegible]
6 455	1,219	1 95	17	2,495		[illegible]	[illegible]	427	383	515	[illegible]	[illegible]	195	[illegible]	[illegible]	[illegible]	[illegible]		
6 950	**1 364**	**2 00**	**18**	**2 800**	[illegible]	**1 408**	**457**	**436**	**419**	**505**	**817**	**856**	**223**	**236**	**430**	**521**	**11 1**	**4 3**	**7 2**
7 [illegible]92	1 584	2 20	17	2 738		[illegible]	486	413	428	484	[illegible]	[illegible]	212	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
7 268	1 321	2 [illegible]	13	2 338		[illegible]	460	354	369	490	[illegible]		194	[illegible]		[illegible]	[illegible]	[illegible]	6 3
10 040	1,885	3 01	19	2 6[illegible]		[illegible]	668	524	587	648	1 10[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8 1
8 810	1 701	2 54	25	[illegible]		[illegible]	427	567	584	596			239*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8 6
7 567	1 523	2 10	16	[illegible]		[illegible]	454	413	403	498	[illegible]	[illegible]	216	[illegible]		[illegible]	[illegible]	4 [illegible]	7 0
8 320	**1 603**	**2 42**	**18**	**2.510**	[illegible]	**1 683**	**495**	**454**	**474**	**543**	**886**	**915**	**225**	**235**	**381**	**411**	**11 7**	**4 7**	**7 5**
9 117	1 787	2 60	23	2,84[illegible]		[illegible]		441	419	552	[illegible]	[illegible]	182	186	[illegible]	[illegible]	11 2	4 6	9 0
8 858	1 928	2 [illegible]	33	3 4[illegible]		[illegible]	[illegible]	464	458	580	[illegible]	[illegible]	196	194	[illegible]	[illegible]	[illegible]	5 1	8 7
8,798	1 990	2 16	30	[illegible]		[illegible]	[illegible]	526	467	624	[illegible]	[illegible]	212	194	[illegible]	[illegible]	[illegible]	5 5	9 1
				[illegible]*		[illegible]*	[illegible]	463	451	553	1 [illegible]	5	207	218		[illegible]	[illegible]	4 5	7 1
8 990	1 8[illegible]	2 49	25	3 5[illegible]		[illegible]	[illegible]	422	457	524	[illegible]	[illegible]	219	[illegible]	[illegible]	[illegible]	[illegible]	4 5	8 1
8 940	**1 878**	**2 38**	**25**	**3.430**	[illegible]	**1 932**	**835**	**463**	**450**	**568**	**881**	[illegible]	**203**	**198**	**344**	**372**	**11 9**	**4 8**	**8 4**

VARIATIONS SHIPMENT 2 100 PER CENT.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	101 9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	105 3	95 6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
100 0	100 0	100 0	100 0	[illegible]		[illegible]	[illegible]	100 0	100 0	100 0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100 0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	11 1		[illegible]	[illegible]	[illegible]		[illegible]		10 4	-11 3
[illegible]	14 6	[illegible]	[illegible]	[illegible]			[illegible]	1 9	[illegible]	4 4	[illegible]	[illegible]	-10 8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-10 7
0 0	0 0	0 0	[illegible]	[illegible]		[illegible]	[illegible]	0 0	0 0	[illegible]	[illegible]	[illegible]	0 0	[illegible]		[illegible]		0 0	0 0

TABLE 8—RESULTS OF TESTS ON SMALL CLEAR SPECIMENS — GREEN DOUGLAS FIR (CO[illegible]

MAXIMA AND MINIMA TREE AV[illegible]AGES AND INDIVIDUAL TES[illegible]

	[illegible]	[illegible]	[illegible]	Specific gravity, based on weight oven dry, when tested	Specific gravity, on volume when oven dry	Fibre stress at elastic limit, per square inch	Modulus of rupture, per square inch	Modulus of elasticity, per square inch	Work in bending per cubic inch: To elastic limit	Work in bending per cubic inch: To maximum load	Work in bending per cubic inch: Total	Fibre stress at elastic limit, per square inch
SHIPMENT No. 1—MOUNTAIN FIR FROM MORLEY, ALTA.		[illegible]	Per cent			Pounds.	Pounds.	1,000 pounds	Inch pounds	Inch pounds	Inch pounds.	Pounds
General average for shipment	**26.2**	25	**34.7**	**0.421**	**0.458**	**3,[illegible]80**	**6,770**	**1,232**	0.69	**7.6**	**12.6**	**6,950**
Maximum tree average	32.8		37.5	0.452	0.492	4,141	7,363	1,368	0.72*	9.0	15.5*	8,590*
Minimum tree average	19.0		33.3	0.385	0.419	3,550*	5,960*	977*	0.65	5.5	11.4	5,633
[illegible]	[illegible]		[illegible]	0.508	0.499	4,380	7,745	1,495	0.79	10.9	15.5	8,590
[illegible]	[illegible]		[illegible]	0.367	0.401	3,550	5,620	977	0.58	2.9	9.9	4,820
[illegible] above gen. avg. per cent	25.2		8.1	7.4	7.4	6.7	8.8	11.0	4.3	18.4	23.0	23.6
[illegible] below gen. avg. per cent	27.5		4.0	8.6	8.5	8.5	12.0	20.7	5.8	27.6	9.5	19.0
[illegible] above gen. avg. per cent.	98.5		24.8	20.7	9.0	12.9	14.4	21.4	14.8	43.4	23.0	23.6
[illegible] below gen. avg. per cent	54.2		14.4	12.8	12.4	8.5	17.0	20.7	15.9	61.8	21.4	30.6
SHIPMENT No. [illegible]—MOUNTAIN FIR FROM GOLDEN, [illegible]												
General average for shipment	**17.4**	32	**33.0**	**0.441**	**0.483**	**4,390**	**7,530**	**1,488**	**0.74**	**6.9**	**14.9**	**8,320**
[illegible]	26.5		[illegible]	0.495	0.549	5,109	8,784	1,676	[illegible]	8.3	19.2	10,040
[illegible]	14.5		31.8	0.396	0.423	3,903	6,462	1,204	[illegible]	5.6	10.6	[illegible]
[illegible]	[illegible]		[illegible]	0.543	0.586	5,720	9,210	1,783	[illegible]	12.7	21.7	10,940
[illegible]			[illegible]	[illegible]	0.385	3,135	6,070	1,020	[illegible]	3.0	8.4	6,850
[illegible]	[illegible]			[illegible]	13.7	16.4	16.7	12.6	28.4	[illegible]	28.8	20.7
[illegible]	[illegible]			10.2	12.4	11.1	14.2	19.1	[illegible]	[illegible]	28.9	12.6
[illegible]	[illegible]			[illegible]	21.3	30.3	22.3	19.8	[illegible]	[illegible]	45.6	31.5
[illegible]	[illegible]		[illegible]	[illegible]	20.3	28.6	19.4	31.5	[illegible]	[illegible]	45.6	17.7
SHIPMENT No. [illegible]												
General average for shipment	**13.3**	38	**31.7**	**0.443**	**0.488**	**5,210**	**8,180**	**1,736**	**0.88**	**6.5**	**18.4**	**8,940**
[illegible]	[illegible]			[illegible]	[illegible]	5,907	[illegible]	1,963		[illegible]	[illegible]	9,117
[illegible]	[illegible]			[illegible]	[illegible]	4,642	[illegible]	[illegible]		[illegible]	16.3	[illegible]
[illegible]	[illegible]		[illegible]	0.540	[illegible]	[illegible]	10,140	[illegible]		[illegible]	[illegible]	9,840
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	7,560
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	13.4	[illegible]	[illegible]		[illegible]	7.6	[illegible]
[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			10.3	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	30.5	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]

*[illegible]

...AS FIR (COAST AND MOUNTAIN VARIETIES) FROM THREE [illegible] MILLS IN ALBERTA AND BRITISH COLUMBIA

...IDUAL TEST VALUES, WITH PERCENTAGE VARIATIONS FROM SHIPMENT AVERAGES.

Impact Bending.				Compression parallel to grain.			Compression perpendicular	Hardness.			Shearing parallel to grain.		Cleavage.		Tension perpendicular to grain		[illegible]	[illegible]	
								Load required to imbed a 0·444 inch sphere of steel to one-half its diameter.			Shearing strength per square inch, the plane of failure being		Splitting strength per inch of width of specimen, [illegible] plane of failure being.		Tensile strength per square inch, the plane of failure being				
Fibre stress at elastic limit, per square inch.	Modulus of elasticity, per square inch.	Work in bending to elastic limit, per cubic inch of specimen.	Height of drop of 51·75-lb hammer causing complete failure of specimen.	Compressive stress at elastic limit, per square inch.	Crushing strength at maximum load per square inch.	M[illegible]	Compressive stress at elastic [illegible]	Radial surface.	Tangential surface.	End surface.	Radial.	Tangential.	Radial.	Tangential.	Radial.	Tangential.	[illegible] green	Radial.	Tangential.
Pounds.	1,000 pounds.	Inch pounds.	Inches.	Pounds.	Pounds.	[illegible]	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Per cent.	Per cent.	Per cent.
6,950	**1,364**	**2·00**	**18**	**2,800**	**2,960**	**1,408**	**457**	**436**	**419**	**505**	**817**	**856**	**223**	**236**	**430**	**521**	**11·1**	**4·3**	**7·2**
8,590*	1,448*	2·86*	29*	3,154	3,318	[illegible]	493	453	447	528	944	936	238	248*	505*	621*	12·8	4·9	[illegible]
5,633	1,219	1·35	12*	2,495	2,763	[illegible]	402	412	383	475	760*	762*	195	214*	349*	380	9·4	[illegible]	6·6
8,590	1,448	2·86	29	3,381	3,475	[illegible]	619	515	500	582	960	1,000	247	267	505	621	[illegible]	4·9	[illegible]
4,820	1,130	1·02	12	2,4[illegible]5	2,550	[illegible]	366	342	337	450	735	704	185	180	349	376	9·0	[illegible]	6·6
23·6	6·2	43·0	61·1	12·6	12·1	[illegible]	7·9	3·9	6·7	4·6	15·5	9·3	6·7	5·1	17·4	19·2	15·3	14·0	4·2
19·0	10·6	32·5	33·3	10·9	6·7	[illegible]	12·0	5·5	8·6	5·9	7·0	11·0	12·6	9·3	18·8	27·1	15·3	11·6	8·3
23·6	6·2	43·0	61·1	20·8	17·4	[illegible]	35·4	18·1	19·3	15·2	17·5	16·8	10·8	13·1	17·4	19·2	18·0	14·0	4·2
30·6	17·2	49·0	33·3	11·6	13·8	[illegible]	19·9	21·6	19·6	10·9	10·0	17·8	17·0	23·7	18·8	27·8	18·9	11·6	[illegible]
8,320	**1,603**	**2·42**	**18**	**2,510**	**3,380**	**1,683**	**495**	**454**	**474**	**543**	**886**	**915**	[illegible]	**235**	**381**	**411**	**11·7**	**4·7**	**7·5**
10,040	1,885	3·01	25	2,738	3,974	[illegible]	668	567	587	648	1,109	1,155		256*	460	520*	12·7	6·1	[illegible]
7,268	1,321	2·10	13	2,314	3,039	[illegible]	427	354	369	484	802	827	194	196	337	32[illegible]	[illegible]	[illegible]	[illegible]
10,940	1,951	3·55	26	3,040	4,570	[illegible]	884	630	667	707	1,154	1,237	287	271	482	551	13·3	6·1	[illegible]
6,850	1,247	1·65	8	1,970	2,380	[illegible]	246	300	345	417	666	714	165	191	269	274	8·3	3·5	5·1
20·7	17·6	24·4	38·9	9·1	17·5	[illegible]	34·9	24·9	23·8	19·3	25·2	26·2	16·[illegible]	8·9	20·7	26·5	8·5	29·8	14·[illegible]
12·6	17·6	13·2	27·8	7·8	10·1	[illegible]	13·7	22·0	22·2	10·9	9·5	9·6	13·8	16·6	11·5	20·4	14·5	25·5	16·0
31·5	21·7	46·7	44·4	21·1	35·2	[illegible]	78·6	38·8	40·7	30·2	30·2	35·2	27·[illegible]	15·3	26·5	34·1	13·7	29·8	11·7
17·7	22·2	31·8	55·6	21·5	29·6		50·3	33·9	27·2	23·2	24·8	22·0	26	18·7	29·4	33·3	29·1	25·5	32·0
8,940	**1,878**	**2·38**	**25**	**3,430**	**4,010**	[illegible]	**535**	**463**	**450**	**568**	**881**	**930**	**203**	**198**	**344**	**372**	**11·9**	**4·8**	**8·4**
9,117	1,996	[illegible]	30	3,715*	4,397		[illegible]	526	467	624	1,002	1,015	[illegible]	218	413	[illegible]	[illegible]	[illegible]	[illegible]
8,[illegible]	1,787	[illegible]	23	2,843	3,785		512	422	419	524	677	828	[illegible]	186	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9,840	2,130	2·85	34	4,855	5,440		866	642	635	730	1,056	1,137	[illegible]	244	452	[illegible]	[illegible]	[illegible]	[illegible]
7,560	1,520	[illegible]	19	1,715	2,18[illegible]		[illegible]	370	333	430	640	750	[illegible]	154	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2·0	6·0	[illegible]	20·0	[illegible]	[illegible]		[illegible]	13·6	3·8	9·9	13·7	9·1		10·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4·8	[illegible]	8·0	17·1	[illegible]		[illegible]	8·9	6·9	[illegible]	23·2	11·0	[illegible]	6·1	[illegible]	[illegible]		[illegible]	[illegible]
10·1	[illegible]	[illegible]	36·0	41·5	[illegible]		61·9	[illegible]	41·1	28·5	19·9	[illegible]	[illegible]	23·2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15·4	19·1	21·8	24·0	50·0	[illegible]		[illegible]	[illegible]	26·0	24·3	27·4	19·4	[illegible]	22·2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Air dry	[illegible]	0 449		8 460	13 340	1 664	[illegible]	8 4		
Air dry	19 7	0 474		9 540	13 620	1 806		11 8	19 7	13 650
Air dry	11 1	0 478		8 990	14 050	2 142		9 9	36 6	10 200
[illegible] shipments	[illegible]	[illegible]		102 7	83 2	26 6		44 6	65 4	39 1

[illegible]	[illegible]	[illegible]	[illegible]	3 770	[illegible]	[illegible]	1 007	739	755	868	1 412	245	[illegible]
13 650	2 114	4 93[illegible]	30	3 790	[illegible]	[illegible]	1 038	679	709	805	1 30[illegible]	305	549
10 200	2 209	2 6[illegible]	33	5 100	[illegible]	[illegible]	946	630	608	724	1 096	244	562
39 1	24 8	58 1	50 9	44 7	124 [illegible]	[illegible]	102 2	51 8	54 9	49 2	44 9	20 2	33 9

erage strength-values, air-dry, for each of the three shipments as given in the same table were obtained by increasing the average values for green timber for these shipments by the corresponding percentages.

Referring to the table it will be seen that the increases in strength from green to air-dry varied very considerably for different strength-values, being on the basis of averages for the three shipments over 200 per cent in the case of work to elastic limit in static bending, and in the neighbourhood of 15 per cent for modulus of elasticity in compression parallel to grain.

For the same strength-value, also, the figures in some cases differ quite considerably for the different shipments. These discrepancies are probably due to two causes:

1. Failure to obtain exactly comparable material for green and air-dry tests
2. Variations in moisture content.

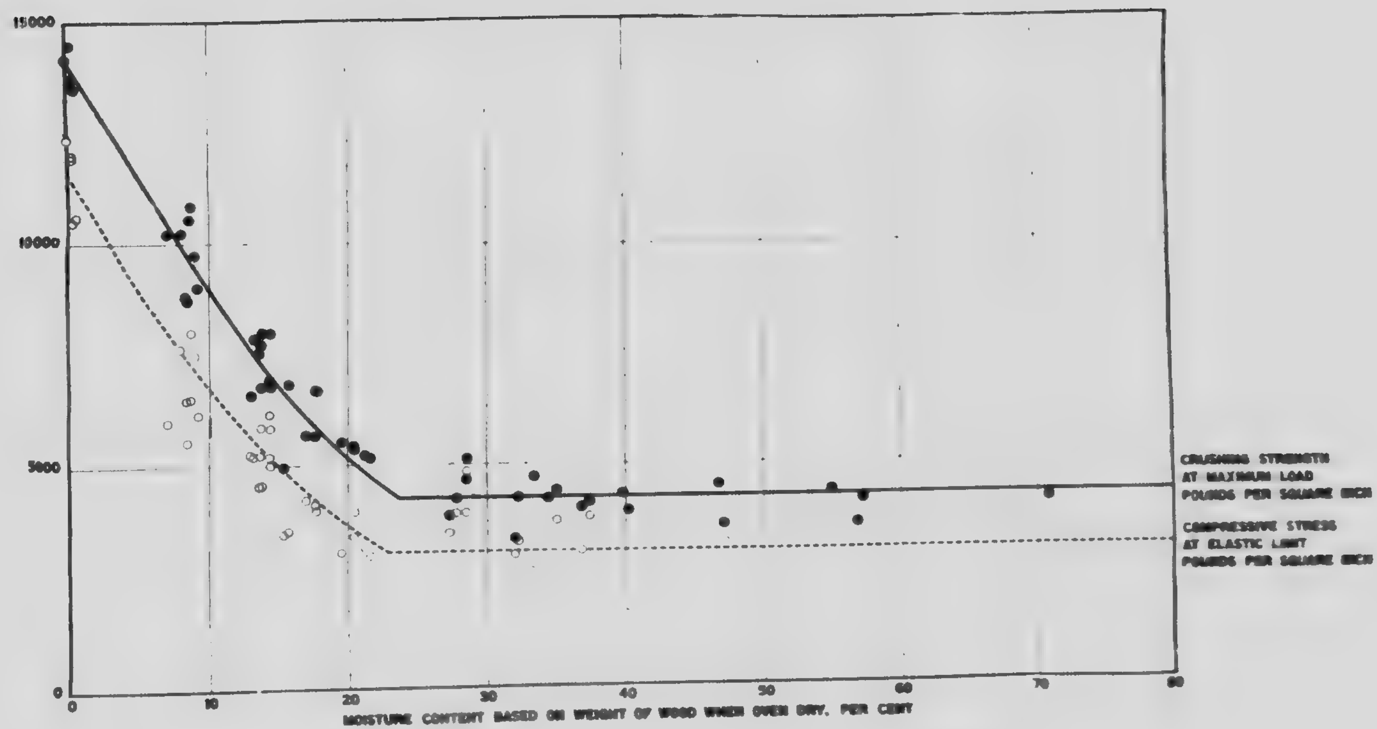
Great care was taken to ensure comparability of the material tested green with that tested dry by correcting for differences in height in the tree, as noted above, and by endeavouring to take, in each case, specimens from the same relative positions throughout the cross-section, so as to avoid errors due to variation in distance of material from the heart. Comparability in this respect is, however, frequently rather difficult to secure, especially in the case of the minor tests in which a comparatively small number of test pieces are used, wood differing widely in strength from point to point in the cross-section.[1]

It is also rather difficult to season even small specimens so as to have all at exactly the same moisture content. As will be seen from the table the average moisture contents for the three shipments varied slightly, and even larger variations occurred for individual specimens of the same shipment.

In Fig. 22 are shown curves of strength for varying conditions of moisture content. These curves are the graphical representation of the results of a series of tests in compression parallel to grain made on specimens taken from one of the logs of Tree 1, Shipment 2, at approximately constant distance from the pith. Some of these specimens were soaked in water for periods of two months and upwards, and tested, others were tested green, others were tested at varying moisture contents from time to time throughout the period of air-drying, and still others were oven-dried and tested. The curves show that the strength remains constant for all moisture contents above a certain critical value, but that below this point any reduction in moisture results in very considerable increases in strength. This point is usually referred to as the fibre saturation point, the theory being that moisture up to this percentage is just sufficient to completely saturate the material of the fibres of the wood, any additional moisture being held as in a sponge, free and without any effect upon the strength or stiffness of the fibres. Any moisture taken away below this point, however, reduces the content of the fibres and results in making them harder and more resistant.

The tests made in this connection under the present investigation were rather incomplete and do not indicate conclusively the precise moisture content at which the fibre saturation point occurs for Douglas fir. It appears, however,

[1]See p. 35.



RELATION OF STRENGTH TO MOISTURE CONTENT.

FIG. 22.—Curves showing relation between moisture content and strength in compression parallel to grain.

Full line shows maximum crushing strength, dotted line represents compressive stress at elastic limit.

that it is somewhere in the interval 22 to 27 per cent moisture, on the basis of the oven-dry weight of the wood.[1]

From consideration of the property of wood illustrated by this curve it will be apparent that all series of tests on timber which it is desirable to have comparable can be made most conveniently in the green condition. Slight variations in moisture content, the occurrence of which it is practically impossible to avoid, have no effect upon strength if the material be green above the fibre saturation point whereas if the timber to be tested is of moisture content below the fibre saturation point slight differences in moisture affect the strength very appreciably. Timber if green is, therefore, in definite, constant condition as regards the strength-moisture relation, although the moisture content may vary considerably, and all tests made on "green" material are, therefore, strictly comparable as far as this relation is concerned.

All species tested, under the investigation of which the above tests on Douglas fir are a part, will, therefore, be compared on the basis of the strength in the green condition.

VARIATION OF PROPERTIES WITH VARIATION OF POSITION IN THE TREE

Material and Methods

For the purpose of determining the amount of variation occurring in the mechanical and physical properties of material from different positions within the same tree of Douglas fir, tests were made on successive four-foot bolts comprising the entire merchantable length of one typical tree of coast type Douglas fir.[2] These tests were in every way similar to those made as the basis for average figures for the three shipments, 2,912 tests in all being made.[3]

In addition to the regular series of tests, measurements of fibre length were also made on material cut from discs of the full section of the tree, taken at intervals of eight feet throughout the length of the same tree. For each disc one annual ring at every twenty years growth, from the periphery to, and including, the first annual ring, was studied, 50 fibres from each ring being measured.

Conclusions

From the results of the above tests and determinations the following general conclusions may be drawn:

1. Wood of least strength and density, and of shortest fibre, occurs at the heart of the tree in the region including, and immediately adjacent to, the pith. Outwards from this region towards the periphery of the tree the

[1]The United States Forest Service gives 23 per cent moisture as the fibre saturation point for Douglas fir. See United States Department of Agriculture, Forest Service, Bulletin 88. Washington, 1911. Cline and Knapp. P. 54.

[2]Tree 1, Shipment 2, coast type Douglas fir from Abbotsford, British Columbia. For a description of this tree see "Material Tested", p. 9.

[3]For description of methods of making tests see Appendix, p. 60.

trength, density, and fibre length increase rapidly at first, and then at a much slower rate, reaching a maximum at the periphery.[1]

2. Variation with height in the tree of the mechanical and physical properties was less in amount and more irregular than from the heart to the periphery, but in general it appeared that:

(1) Density decreased with height in the tree, being greatest at the butt and least at the top of the tree;

(2) Average fibre length reached a maximum at a height of about 42 feet from the ground, decreasing from this point both towards the top and towards the butt and being less at the butt than at the top;

(3) Strength decreased with height in the tree.

Two exceptions to the above general rules should be noted:—

(*a*) Near the top of the tree (Bolts C′ to H′, 116 to 136 feet from the ground) there occurred a region in which the general rule that strongest and densest wood is found at the periphery and weakest and lightest at the heart was reversed, the strongest and densest wood being at the heart. The reason for this occurrence, which is probably an individual peculiarity of the tree, is not understood.

(*b*) In accordance with the general rule that strength decreases with height in the tree it would be expected that the strongest material would be found at the extreme butt. This rule held good for the majority of the strength functions, but in the case of static and impact bending and compression parallel to grain tests the maximum values occurred at heights of from 10 to 30 feet from the ground, and the strength values decreased from these points downwards towards the butt as well as upwards. There appeared to exist near the periphery, in the butt of the tree, a region of dense material of short fibre which was stronger than any other material in the tree in most respects but not correspondingly strong in bending and in compressive strength parallel to the grain.

It was noticeable that the wood in this region was of rather irregular grain, tending towards the occurrence of cross-grain. This would be expected to affect the bending and compression parallel to grain tests to a considerably greater degree than any of the others, and may be the explanation of the occurrence of this unusual condition.

Presentation of Results

It is a rather difficult matter to show graphically by means of curves the variation of properties throughout all parts of a tree, because of the occurrence of variations in two different directions (viz.: with height in the tree and with position in the cross-section), coupled with the fact that a tree tapers from the butt to the top. Thus, the age and diameter being greater at the butt than at the top, if it is attempted to prepare a curve to show the average variation

[1]Similar tests by other investigators (*See* "Timber Physics—Résumé of investigations carried on in the U. S. Division of Forestry, 1889-1898." Filibert Roth 1899. P. 351) show that for longleaf pine strength and density curves after reaching a maximum value drop off toward the periphery in old trees, indicating that in extreme old age timber weaker and less dense than that formed during the period of optimum development is put on. Apparently the tree under investigation had not reached its optimum condition at 177 years, assuming the same law to hold true for Douglas fir. It would appear, therefore, that larger trees of this species commonly occurring on the coast might be expected to contain in their volume in excess of the volume of the tree tested, up to a certain point, timber of strength equal to or greater than the maximum for the tree under consideration. Additional tests on larger trees would be required to determine the age at which the optimum condition is reached in Douglas fir.

of properties from the pith to the periphery for the entire tree, the curve will be distorted whether averages are made throughout the length of the tree at equal distances from the pith or at equal distances from the periphery, owing to the fact that in either case the averages for material farthest from the point of reference (pith or periphery) will include only material from the butt of the tree. The effect of variation in diameter with height in the tree thus becomes a factor in the comparison. For this reason selected representative curves showing the typical variation of properties throughout the cross-section, at various heights in the tree, are probably more enlightening than curves of averages for the entire tree.

Similarly, if curves to show the variation of properties with height in the tree are drawn by plotting averages for the entire cross-section taken at regular intervals throughout the length of the tree, the averages for cross-sections near the butt of the tree will include material much older than occurs in the top, the effect of variation with position in the cross-section being thus involved in the comparison. Consequently, averages for material of the same age only, at all heights through the tree, would be a more reasonable basis for curves to show variation with height in the tree than averages for the entire cross-section. Thus, in the present instance, the tree in question being 88 years old at the top of the merchantable length, averages for the last 88 years' growth only, at intervals throughout the length of the tree, would be a better indication of variations with height in the tree than averages for the entire cross-section.

In accordance with the above discussion typical curves which illustrate the characteristic variation of properties with position in the cross-section, for the tree under consideration, have been selected in the present instance, and are shown in Figs. 23 to 28. All are actual curves for certain definite sections of the tree, as indicated in connection with the figures. Figs. 23 to 25 show the variation of the rate of growth, specific gravity, summer-wood, moisture, and fibre length; and Figs. 27 and 28 show the corresponding variation of the mechanical properties as illustrated by strength in static bending and compression parallel to grain.

It will be observed that there was in general an increase in strength, stiffness, density, and fibre length from the pith towards the periphery, the rate of increase being most rapid at the centre and decreasing towards the periphery. This feature was most pronounced in the case of the fibre length (Fig. 25), which increased by 400 or 500 per cent from the pith to the periphery, the rate of increase being very rapid near the pith and progressively less farther out in the tree, the variation from a point 60 or 70 growth-rings from the pith outwards to the periphery being slight.

The curve of rings per inch (reciprocal of rate of growth) indicates the occurrence of wide growth-rings at the heart and a decrease in width with increasing distance from the pith. The rate of this decrease was slow near the heart, more rapid farther out in the tree, and slow again at a distance of from 10 to 11 inches from the pith. The drop of the curve at the extreme end indicates a decrease in the number of growth-rings to the inch at the periphery. This occurrence of wood of more rapid growth at the periphery of the tree is undoubtedly an individual peculiarity of this particular tree. Similar curves

for other trees showed a steady increase in the number of growth-rings per inch all ·he way to the periphery.

The curve of moisture is peculiar in rising to a very decided maximum at the periphery after decreasing slightly from the pith to within a few inches of the periphery. In similar curves for other trees of the same shipment (coast type fir) this same peculiarity occurred, but for all the trees of the other two shipments (mountain type fir) the curves continued to drop to a minimum at the periphery. Typical curves for the three shipments shown in Fig. 26 illustrate this point very well.

A difference in the season of felling might be suggested as the explanation of this condition by the fact that the two shipments of mountain ty[illegible] in which the increase of moisture at the periphery did not occur were c[illegible]ur[illegible] the winter,[1] whereas four of the five trees of the shipment of coast type [illegible] which the increase did occur were felled during the autumn.[2] This theory [illegible] however, apparently upset by the fact that the fifth tree[3] of the shipment of coast type fir, which in common with the other trees of the same shipment showed a marked increase in moisture at the periphery, was cut during the same month as the shipments of mountain type fir.[1]

There were no marked differences in the treatment received by the three shipments of material after the time of cutting. The explanation of the presence of this region of high moisture content near the periphery in the case of the shipment of coast type fir and its absence in the case of the two shipments of mountain type fir, is, therefore, not apparent, apart from the fact that it may be a manifestation of some inherent difference between the two forms of Douglas fir.

In Figs. 29 to 37 will be found curves which indicate the variation of the various mechanical and physical properties with height in the tree. The solid curves in every case show the variation of averages for all material in successive four-foot bolts throughout the length of the tree. The corresponding dotted curves show the variation of averages for the last 88 years' growth only, for each bolt. It will be observed that the dotted curves in every case reach higher values near the butt than the solid curves, indicating that the presence in the lower bolts of material of greater age than that found in bolts nearer the top has the effect of making the variation in properties of material put on at varying heights in the tree, as indicated by bolt averages, appear less than is actually the case.[4]

As shown by the curves, density, percentage of summer-wood, and amount of shrinkage on oven-drying in general decrease from the butt to the top of the tree in a somewhat irregular manner.

The curve of fibre length has its minimum value at the butt, increases from this point to a maximum value at Bolt J, 42 feet above the ground, and from Bolt J decreases steadily towards the top of the tree, the decrease being less from Bolt J to a point 90 feet above the ground than from this point to the top of the tree.

[1]Month of February, 1913.
[2]Month of September, 1913.
[3]Tree 1, Shipment 2.
[4]See discussion, p. 36.

Rings per inch apparently increase in much the same manner as the fibre length to a maximum value about half-way up the tree, thereafter again decreasing towards the top of the tree. The curve for the last 88 years (dotted) shows this effect to a much greater degree than the curve of bolt averages (solid).

The curves of moisture (Fig. 31) are rather erratic, but in general seem to indicate that the moisture content was slightly greater at mid-height in the tree than at the ends. The curve for the last 88 years' growth (dotted line) reaches considerably higher values than the curve of bolt averages (full line), this being in accord with the fact noted above that a region of high moisture content existed near the periphery of the tree. The slightly upward trend of the curve of the bolt averages (full line) indicates not that higher moisture content existed at the top of the tree but that there was a greater proportion of wet wood in the cross-section of the tree at this point. The zone of high moisture near the periphery, being of constant width, constituted a greater proportion of the total area at the top, where the diameter was relatively small, than at the butt.

The curves for the various mechanical tests indicate a general decrease in strength, stiffness, and toughness with increasing height in the tree, the maximum values occurring at or near the butt and the minimum in the top of the tree. In the case of the bending tests and of compression parallel to grain the curves, in apparent exception to this rule, drop off at the butt somewhat, the maximum value occurring at a height of from 10 to 30 feet above the ground. As explained above this condition is probably due to the presence of cross-grained material which occurred near the periphery in the butt.

The extreme variability of the majority of the curves is probably, for the most part, truly indicative of corresponding irregular variations in the properties of the timber at different heights in the tree. Some of the variations may, however, be due to failure to obtain test pieces truly representative of average conditions throughout the section of the tree at any given height, the effect of the very considerable variations in properties with variation in position in the cross-section being thus made a factor in the comparison.

That the properties do not vary uniformly from point to point throughout the tree, but that pronounced local variations occur, is well illustrated by Figs. 38 to 41. These diagrams, which as a basis for study of the variation of properties throughout the tree are perhaps more enlightening than the two systems of curves presented above, are longitudinal sections through the heart of the tree, drawn, of course, to a much distorted scale, with regions mapped out on them in which the special property under consideration is between certain limits. The region in which the greatest values occur has the heaviest hatching, that in which the minimum values occur has the lightest, and intermediate areas have been indicated by an appropriate graduation of the shading.

Fig. 38 shows in this way the distribution of dense wood throughout the tree. It will be observed that the maximum values occur at the butt of the tree near the periphery and that less dense wood is found upward and inward from this point, the least dense being at the heart. An apparently abnormal reversal of this distribution of light and heavy wood in the top of the tree (Bolts

C′ to K′) is clearly indicated. The presence of a pronounced local variation at Bolt A′, where a region of unusually dense wood occurs, is also shown.

Figs. 39 and 40, in a similar manner, indicate the variation of bending and compressive strength throughout the tree. A broad, general similarity between these diagrams and that for specific gravity, indicating a relationship between strength and density, will be noted. An agreement in all details, of course, does not occur, although the anomalous reversal of the relative location of dense and light-weight wood in the top is paralleled by a similar reversal of strength conditions, and a region of exceptional strength appears in the vicinity of Bolt A′ to correspond with the area of dense wood found at this point.

Fig. 41 illustrates in a similar manner the distribution of moisture throughout the tree.

The data of which the foregoing curves and diagrams are a graphical presentation is given in numerical form in Tables 10, 11, and 12 inside the back cover. Table 10 shows averages for all the various types of test for successive four-foot bolts, comprising the entire merchantable length of the tree. Table 11 gives similar data for the last 88 years' growth of each bolt. In Table 12 the results of certain of the tests are arranged to show the variation, throughout the cross-section, of the more important properties, for each bolt in the tree.

The amounts of the variations of the various properties with differing positions in the tree are shown in Table 10. The maximum percentage variations of the bolt averages from the tree average values are here indicated, and the maximum percentage variations of stick averages from the corresponding bolt averages are also given for those tests of which the results are classified according to distance from the pith. It will be observed that the latter figures are in almost all cases greater than the former. This indicates that greater variations in properties than occur throughout the entire length of the tree, on the basis of the bolt averages, are to be found in certain cross-sections of the tree between the pith and the periphery.

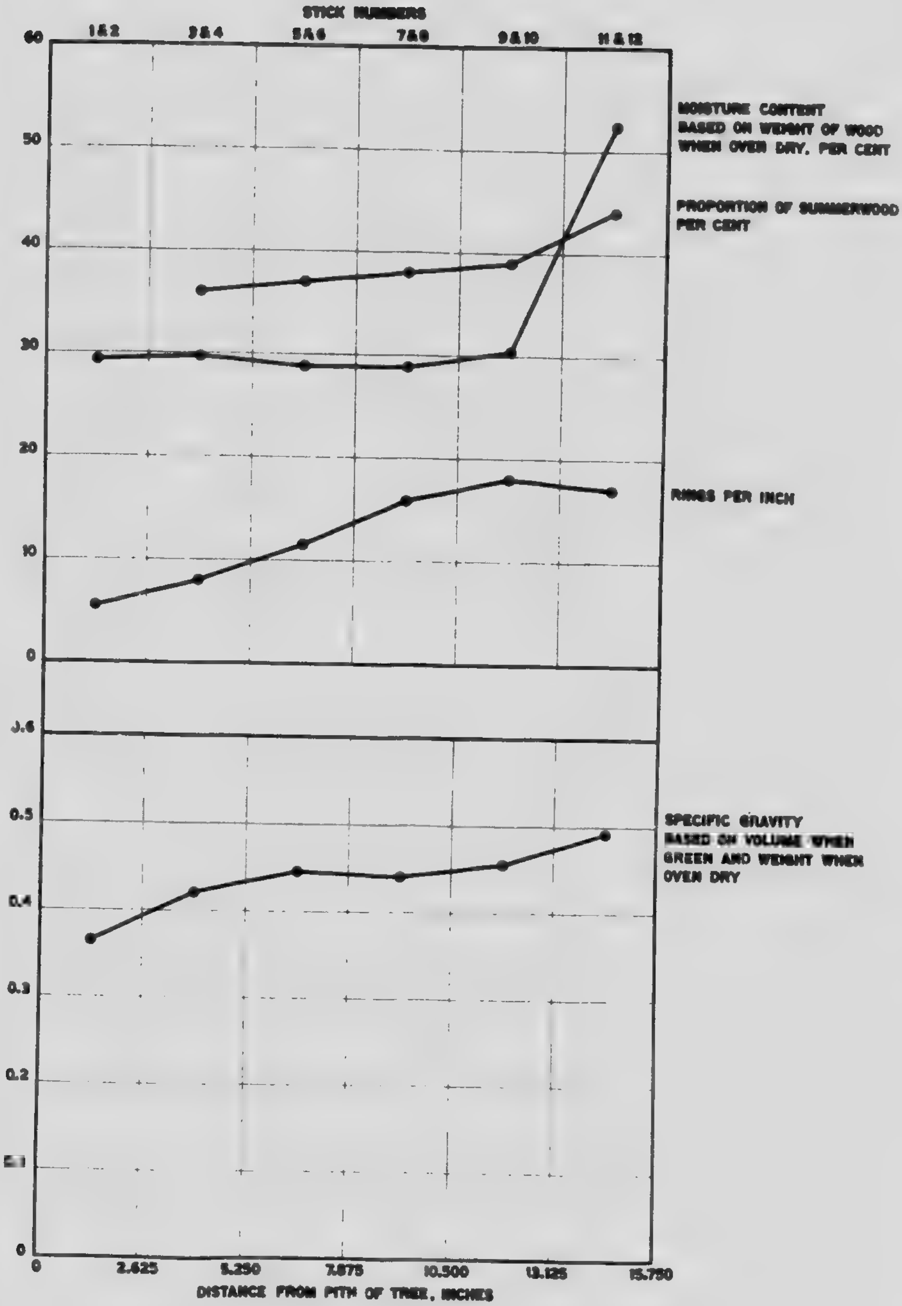


FIG. 23.—Curves showing characteristic variation of physical and structural properties with distance from the pith for Tree 1, Shipment 2, (Bolt D).

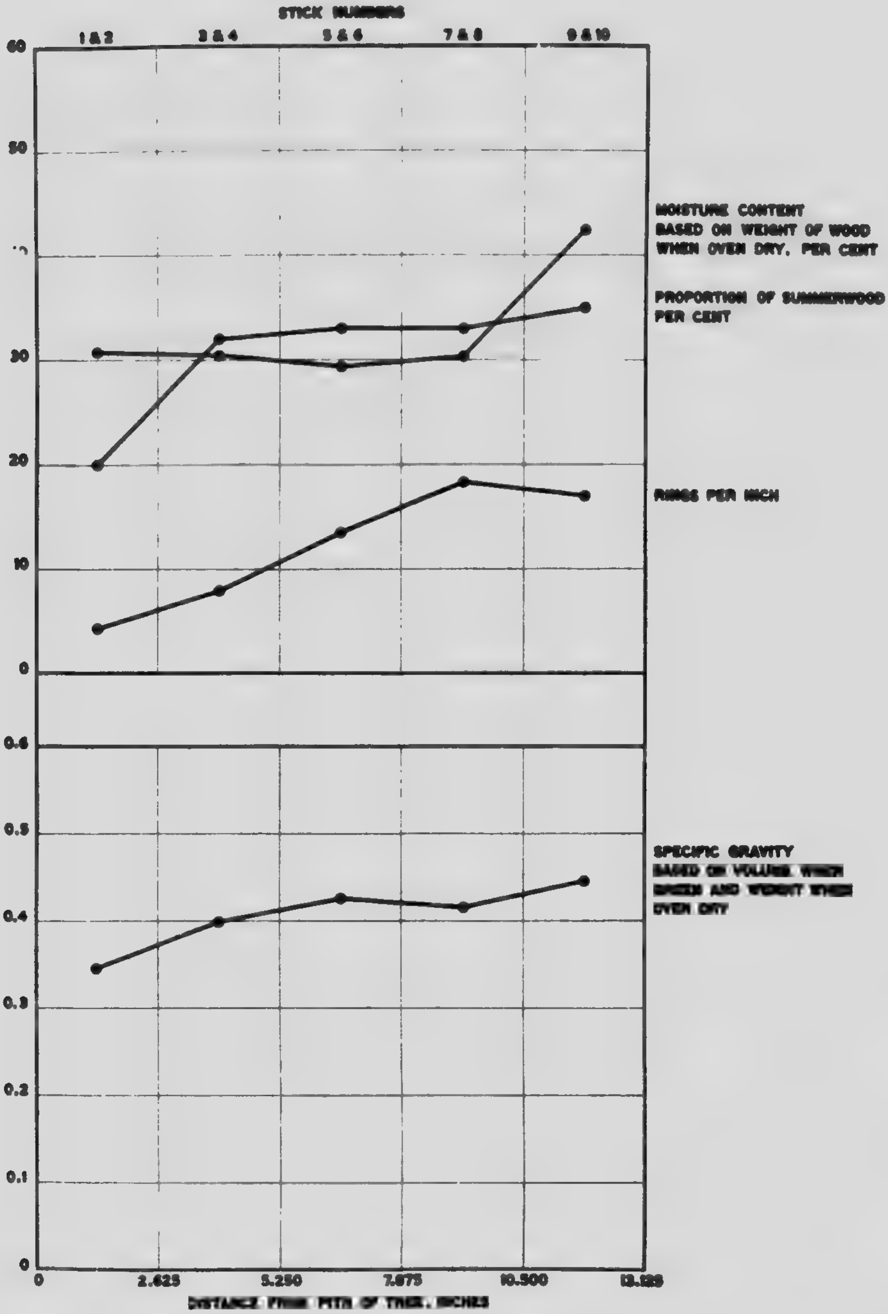


FIG. 24.—Curves showing characteristic variation of physical and structural properties with distance from the pith for Tree 1, Shipment 2, (Bolt J).

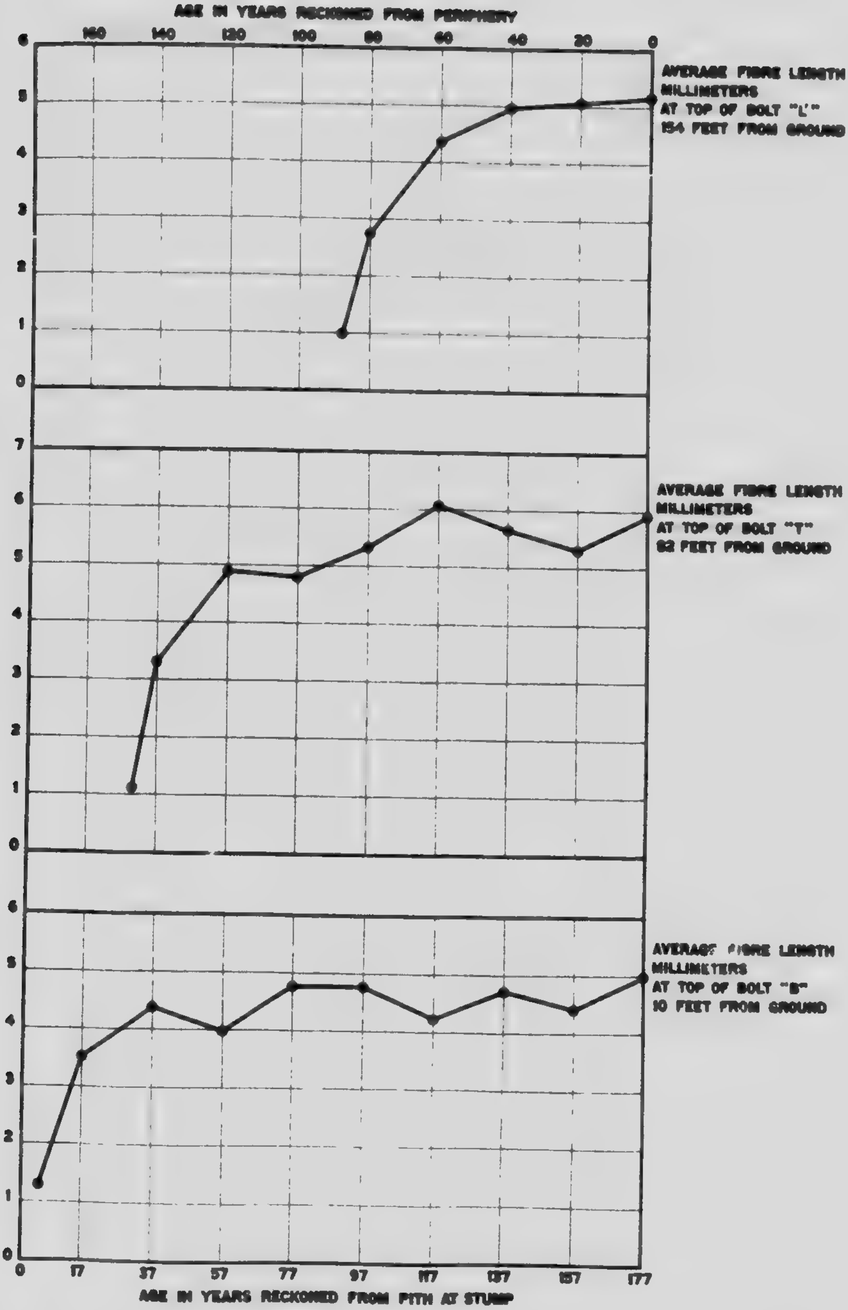


FIG. 25. Curves showing characteristic variation of fibre length from pith to periphery of Tree 1, Shipment 2, (Bolts B, T, and L).

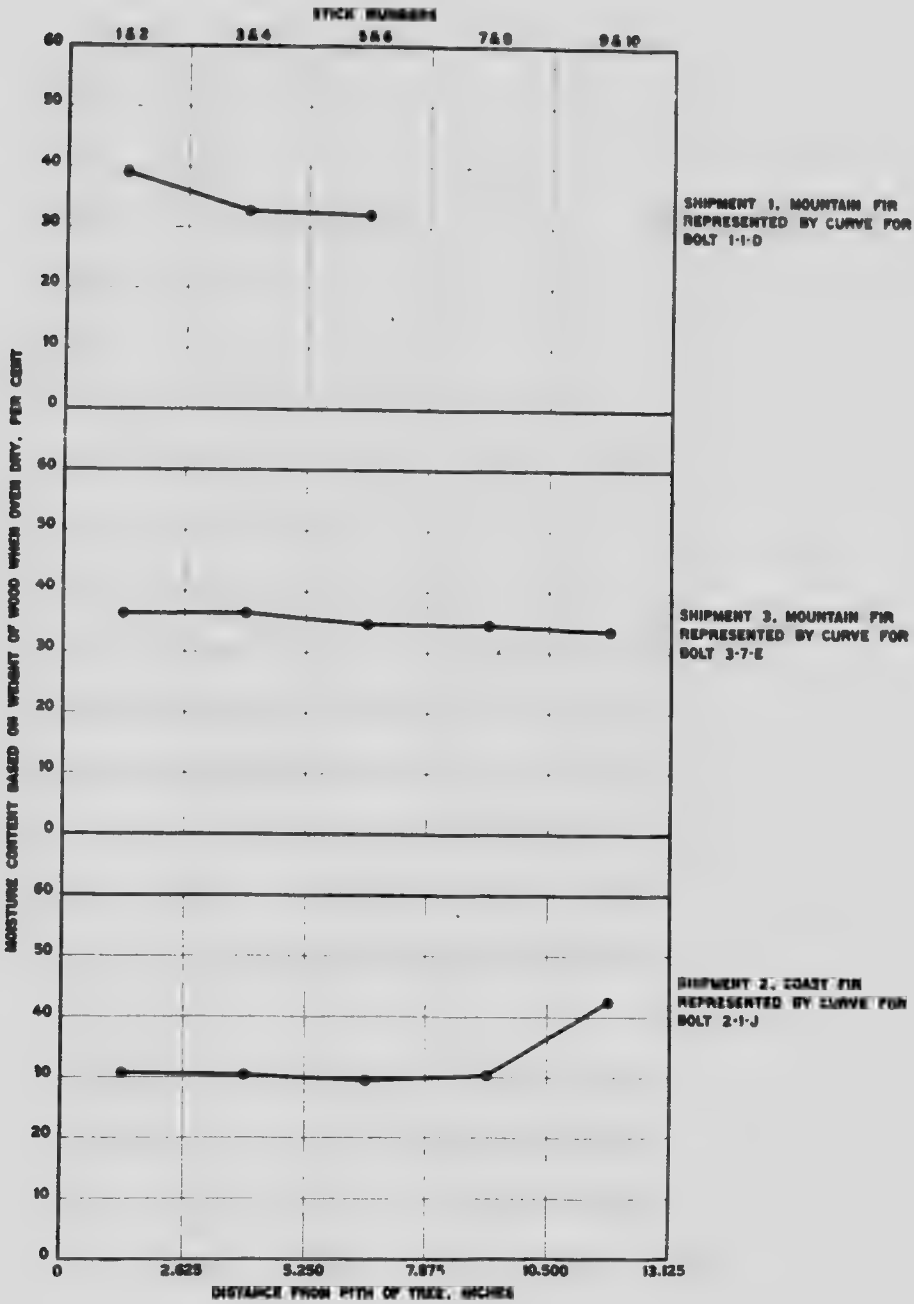


FIG. 26.—Curves showing characteristic variation of moisture content with distance from the pith for Shipments 1. 2. and 3.

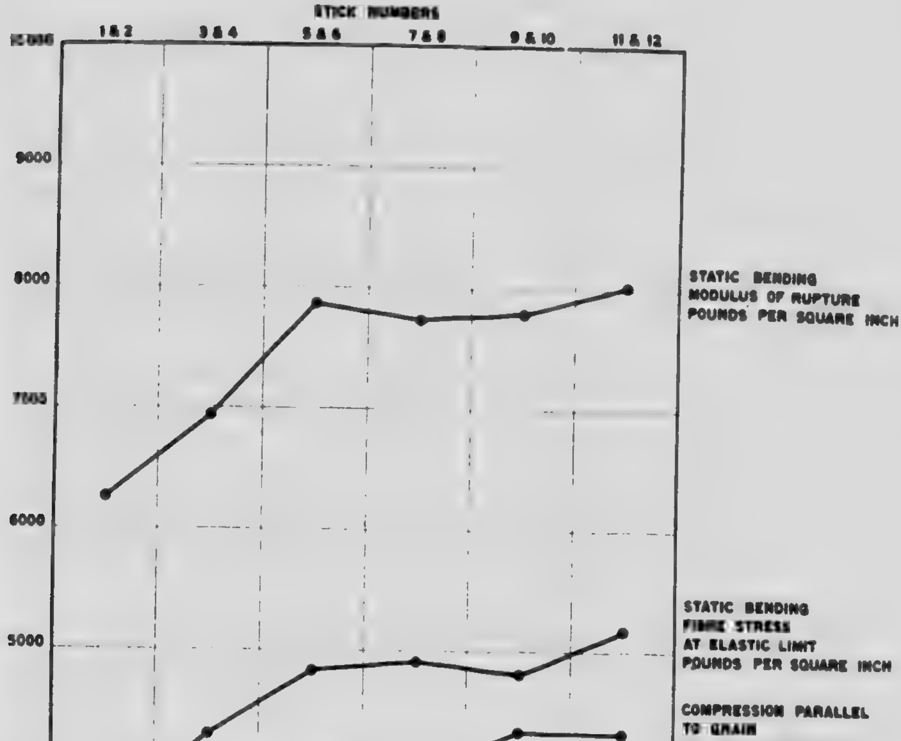


FIG. 27.—Curves showing characteristic variation of mechanical properties with distance from the pith, for Tree 1, Shipment 2 (Bolt D).—Static bending and compression parallel to grain

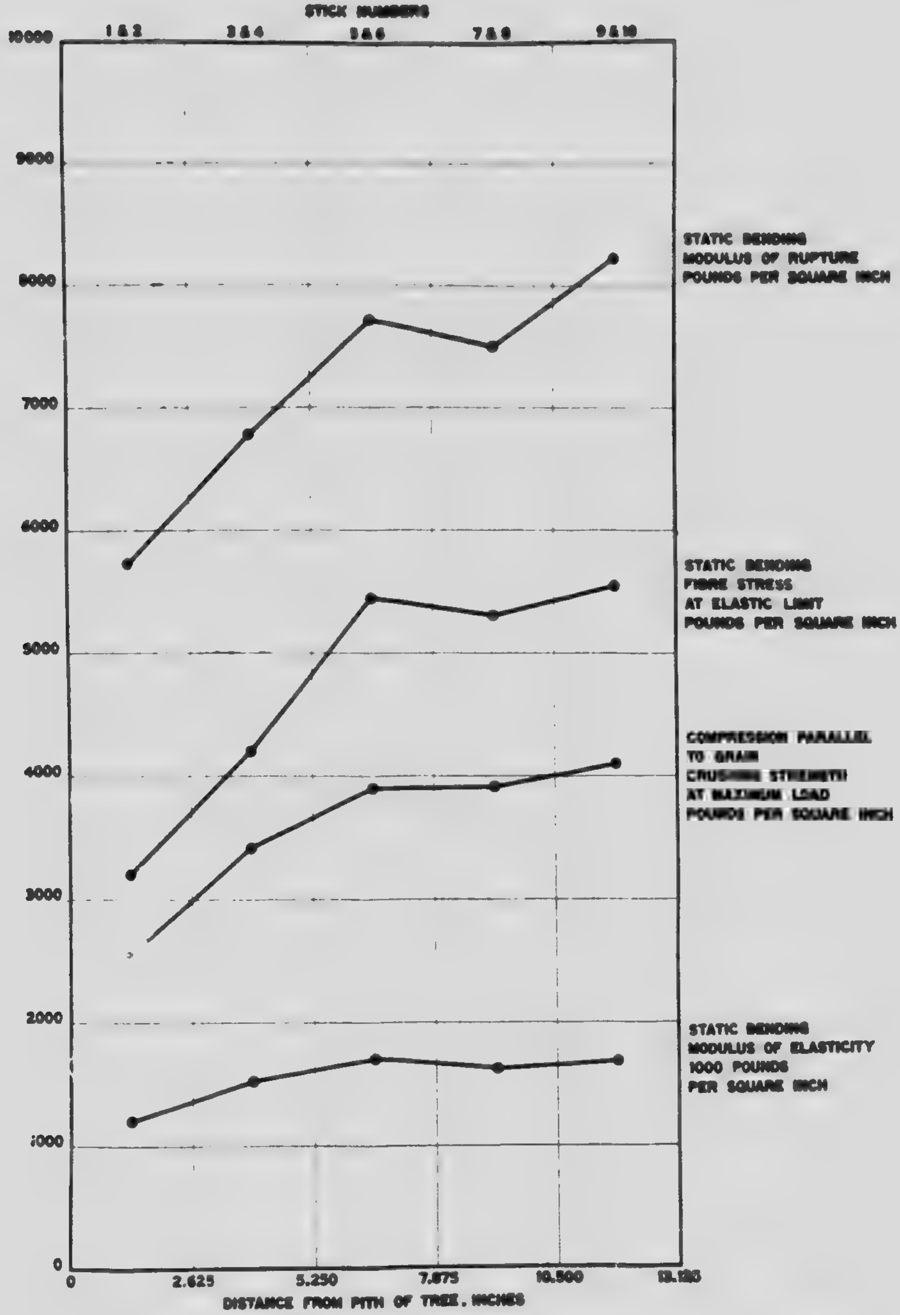


FIG. 28.—Curves showing characteristic variation of mechanical properties with distance from the pith for Tree 1, Shipment 2 (Bolt J).—Static bending and compression parallel to grain.

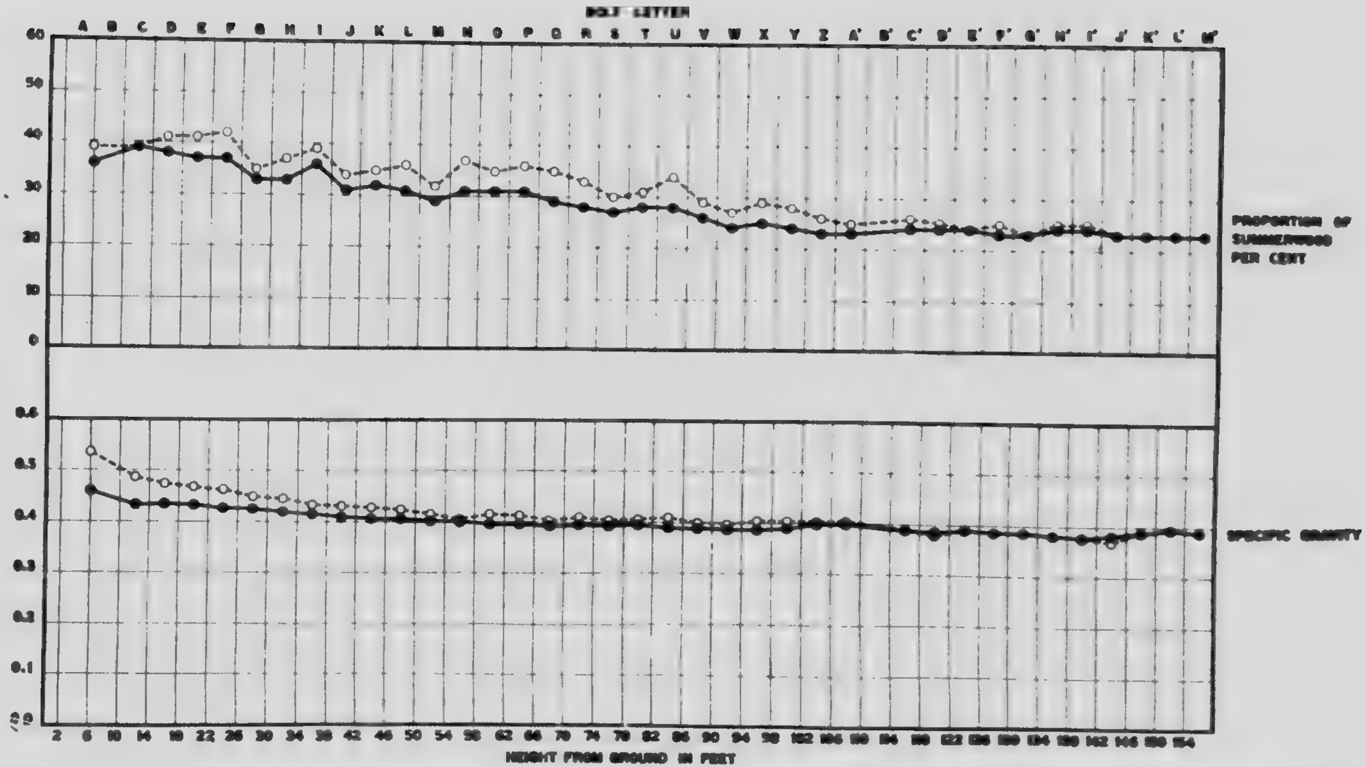


FIG. 29.—Curves showing variation of physical and structural properties with height in tree (Tree 1, Shipment 2).—Per cent summer-wood, and specific gravity based on volume green and weight oven dry

Full line shows averages for entire cross-section of tree, dotted line indicates averages for last 88 years' growth only

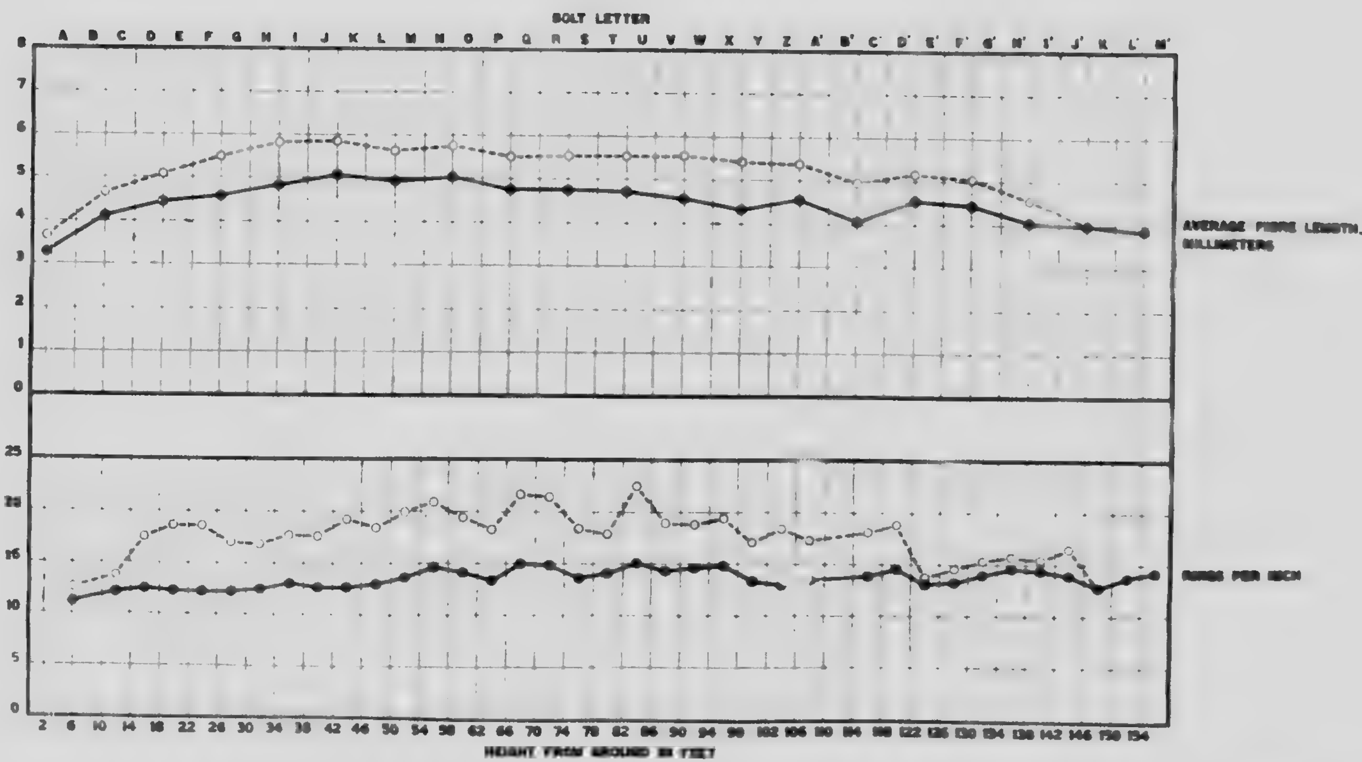


FIG. 30. Curves showing variation of physical and structural properties with height in tree (Tree 1, Shipment 2). Fibre length and rings per inch.

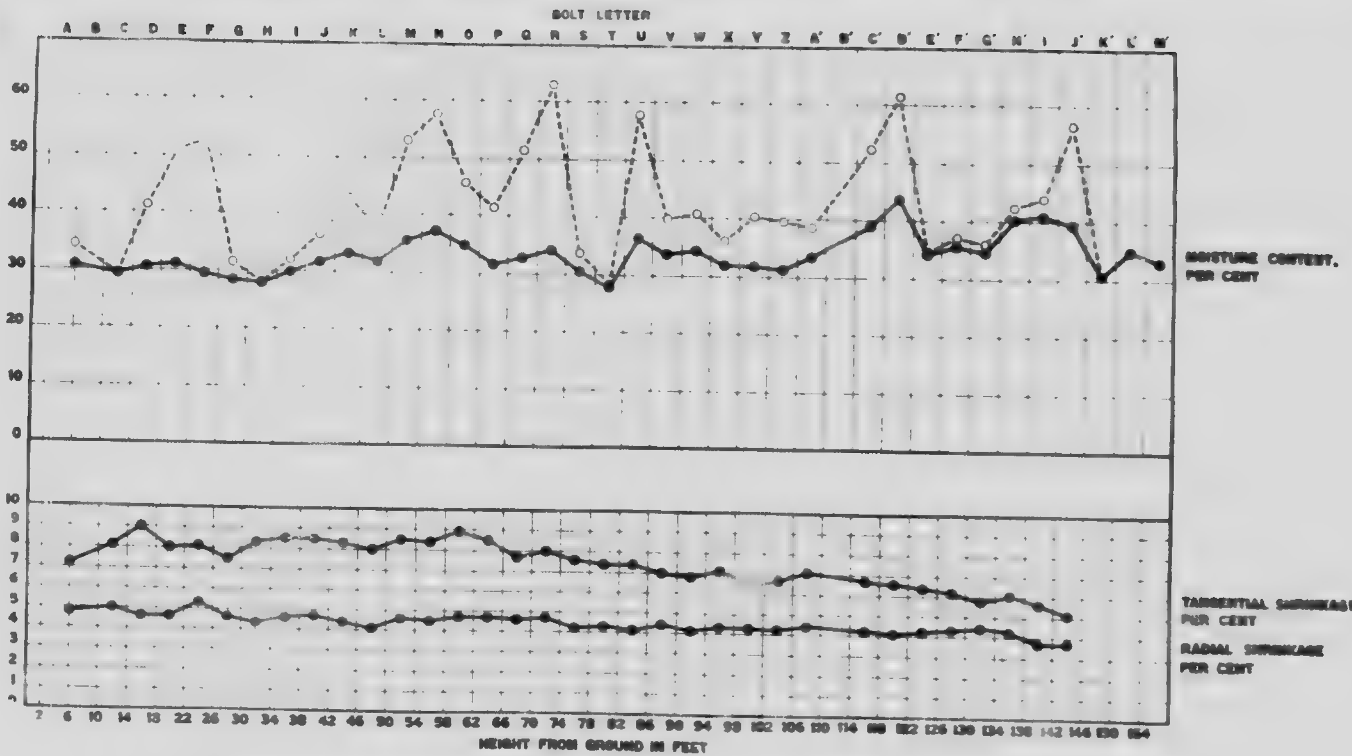


Fig. 31.—Curves showing variation of physical and structural properties with height in tree (Tree 1, Shipment
Moisture content and shrinkage

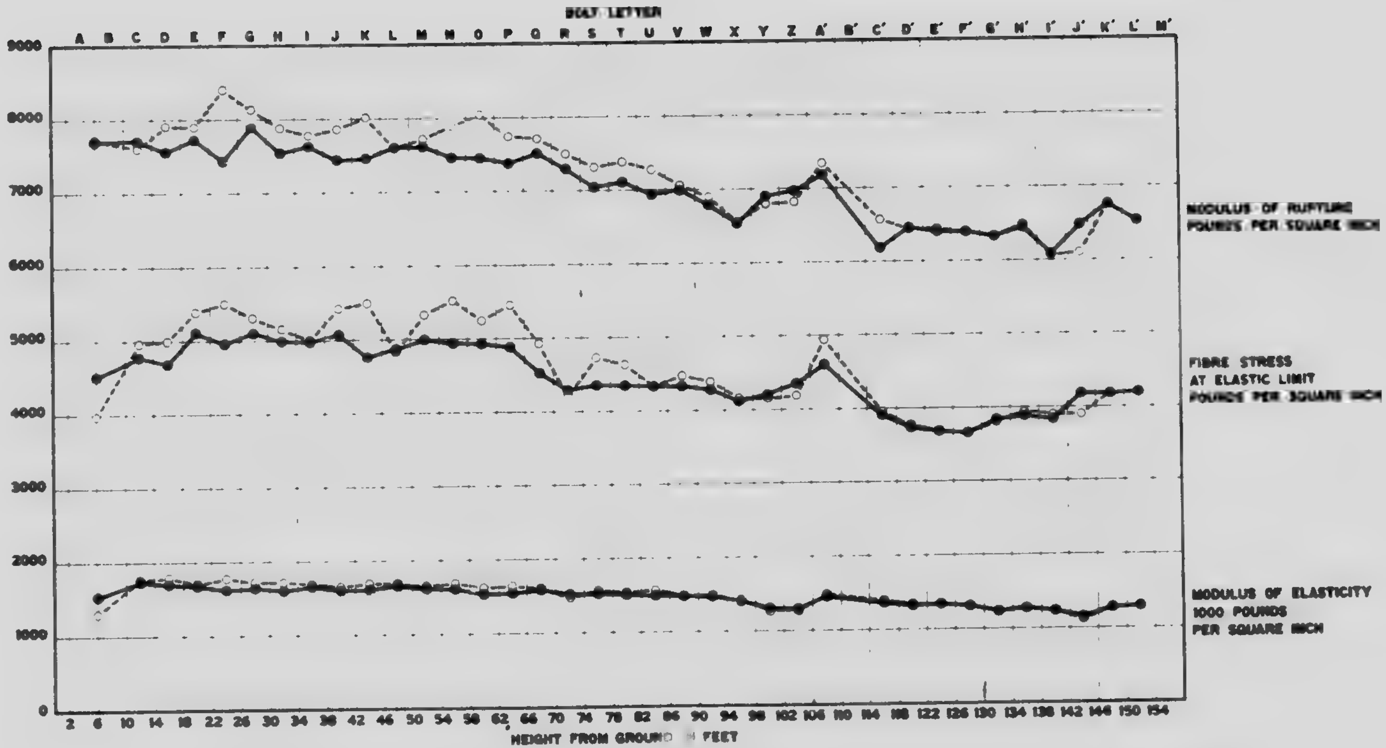


FIG. 32.- Curves showing variation of mechanical properties with height in tree (Tree 1, Shipment 2).—Static bending.

Full line shows averages for entire cross-section of tree, dotted line indicates averages for last 88 years' growth only.

Full line shows averages for entire cross-section of tree, dotted line indicates averages for last 88 years' growth only.

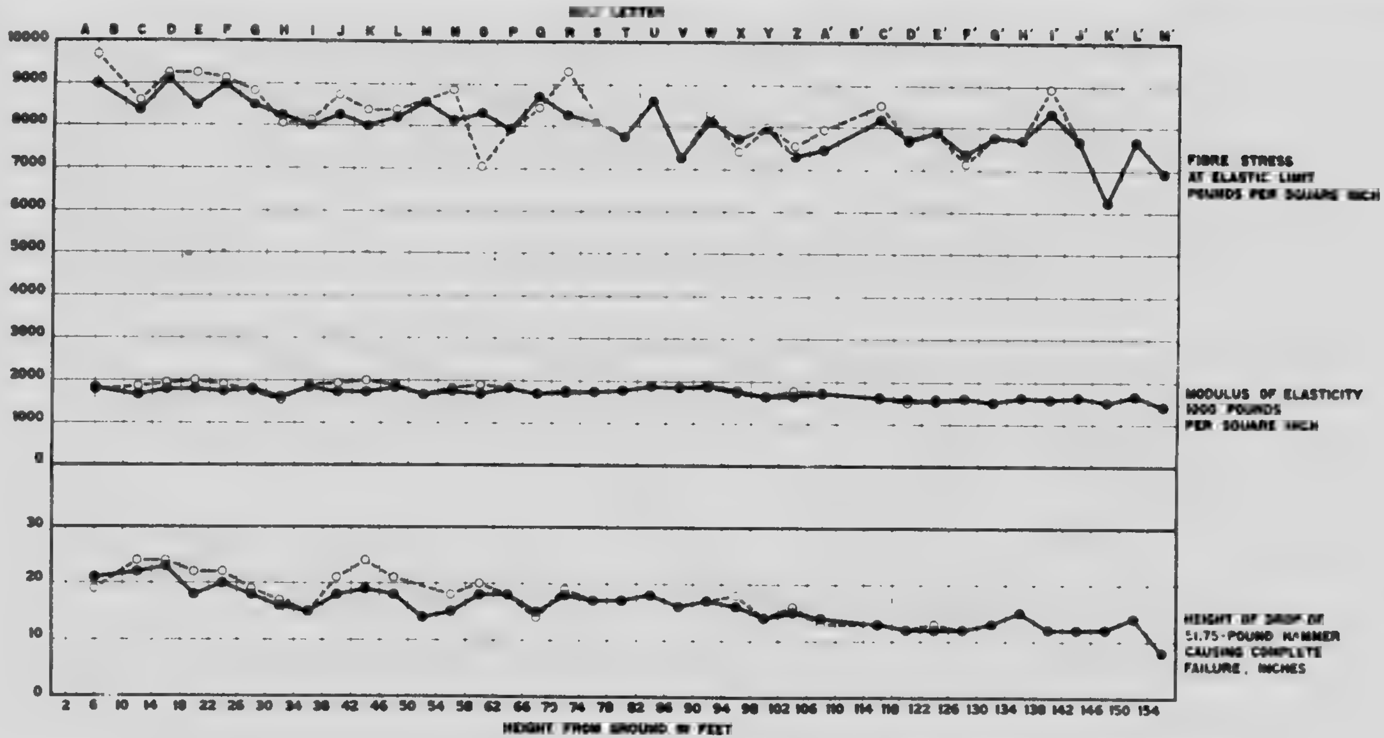


FIG. 33. Curves showing variation of mechanical properties with height in tree (Tree 1, Shipment 2). Impact bending.

Full line shows averages for entire cross-section of tree, dotted line indicates averages for last 88 years' growth only.

28743—4½

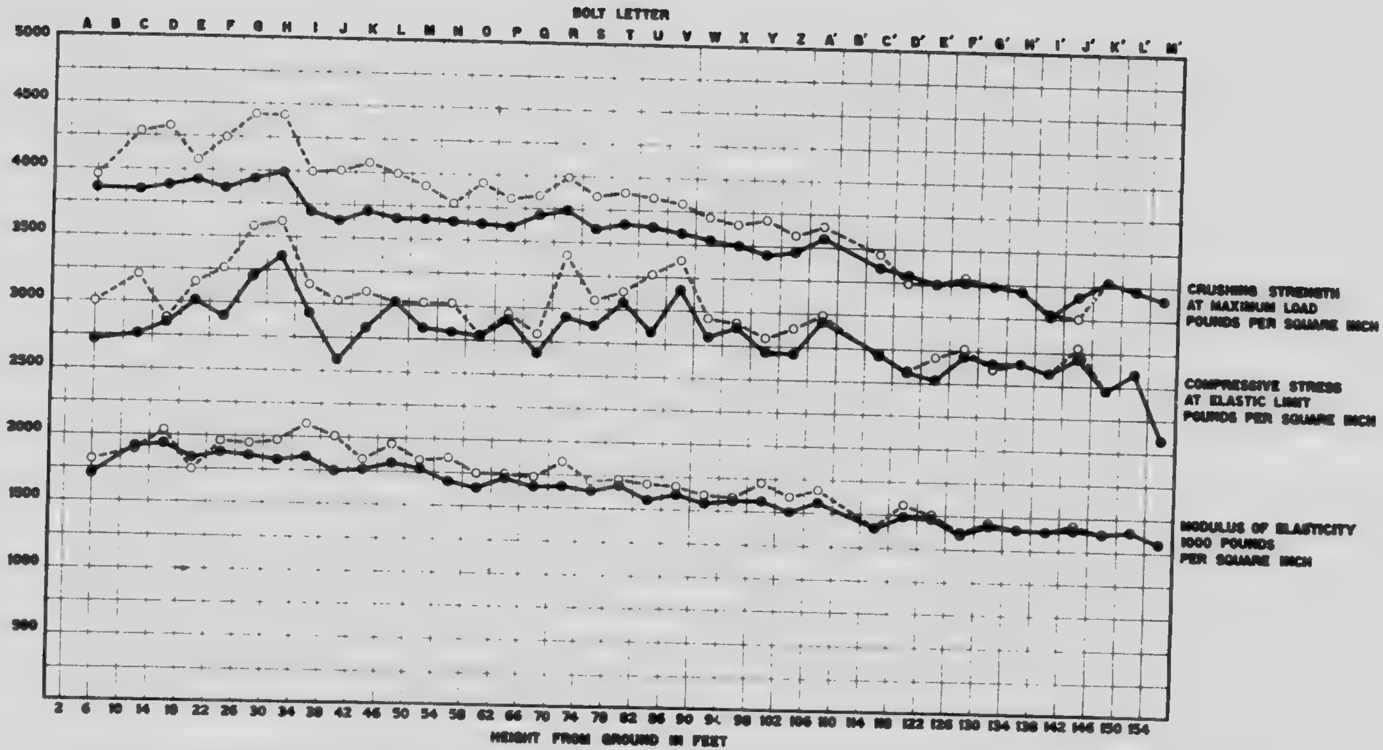


FIG. 34. Curves showing variation of mechanical properties with height in tree (Tree 1, Shipment 2).—Compression parallel to grain.

Full line shows averages for entire cross-section of tree, dotted line indicates averages for last 88 years' growth only.

Full line shows averages for entire cross-section of tree, dotted line indicates averages for last 88 years' growth only.

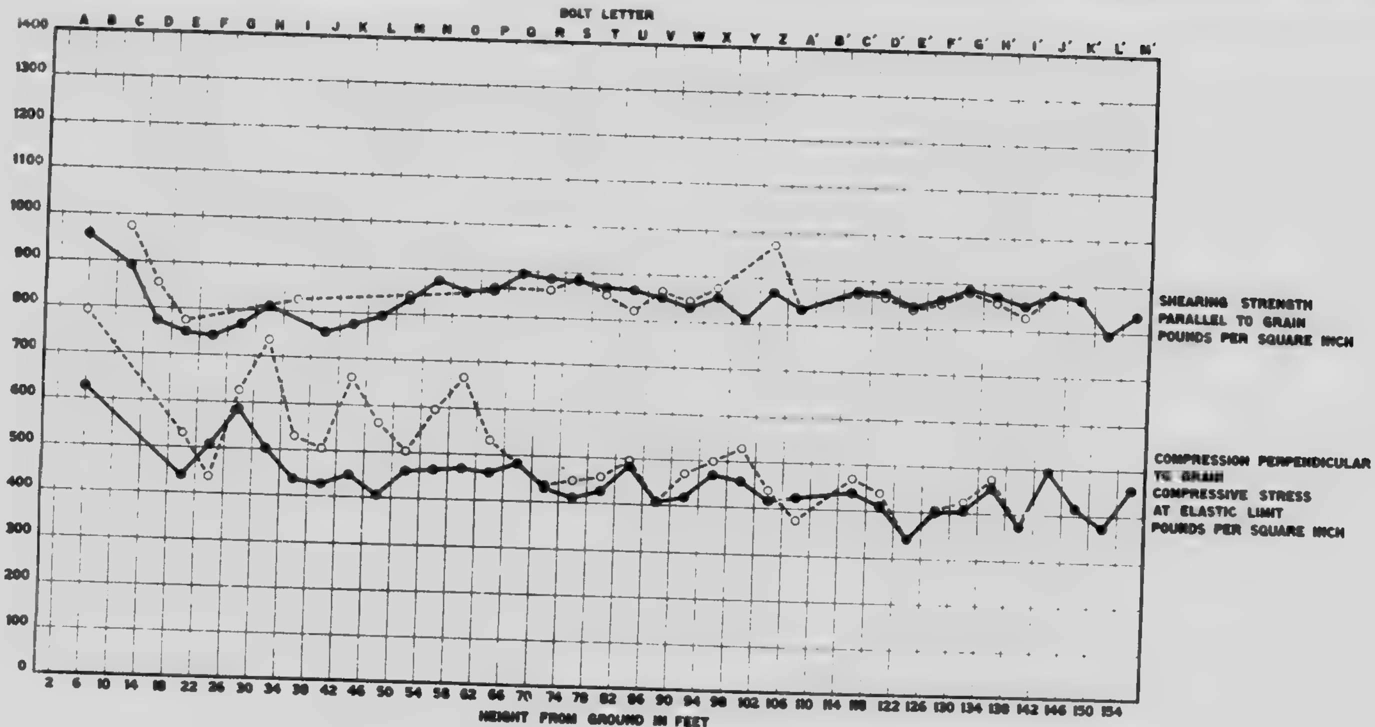


FIG. 35.—Curves showing variation of mechanical properties with height in tree (Tree 1, Shipment 2).—Compression perpendicular to grain and shearing.

Full line shows averages for entire cross-section of tree, dotted line indicates averages for last 88 years' growth only.

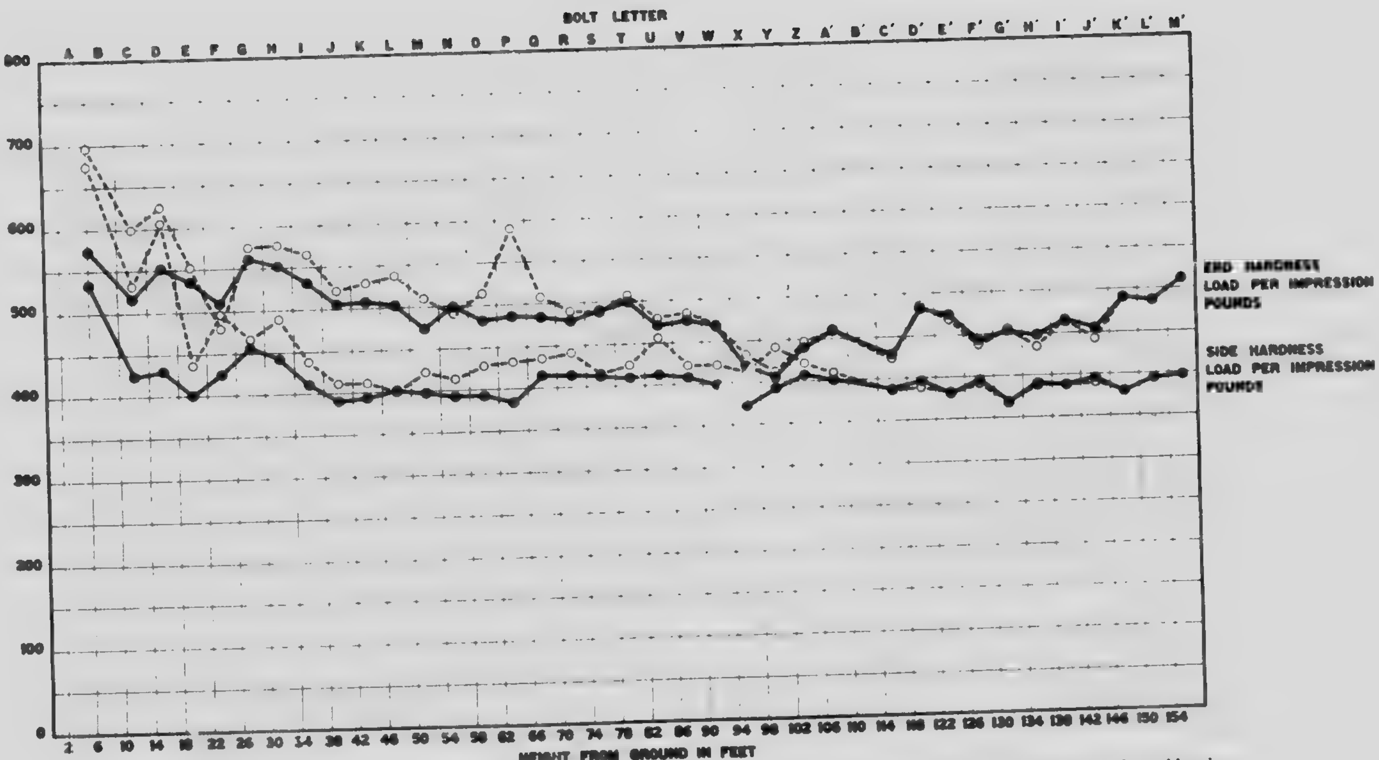


FIG. 36.—Curves showing variation of mechanical properties with height in tree (Tree 1, Shipment 2). Hardness

Full line shows averages for entire cross section of tree, dotted line indicates averages for last [illegible] years' growth only.

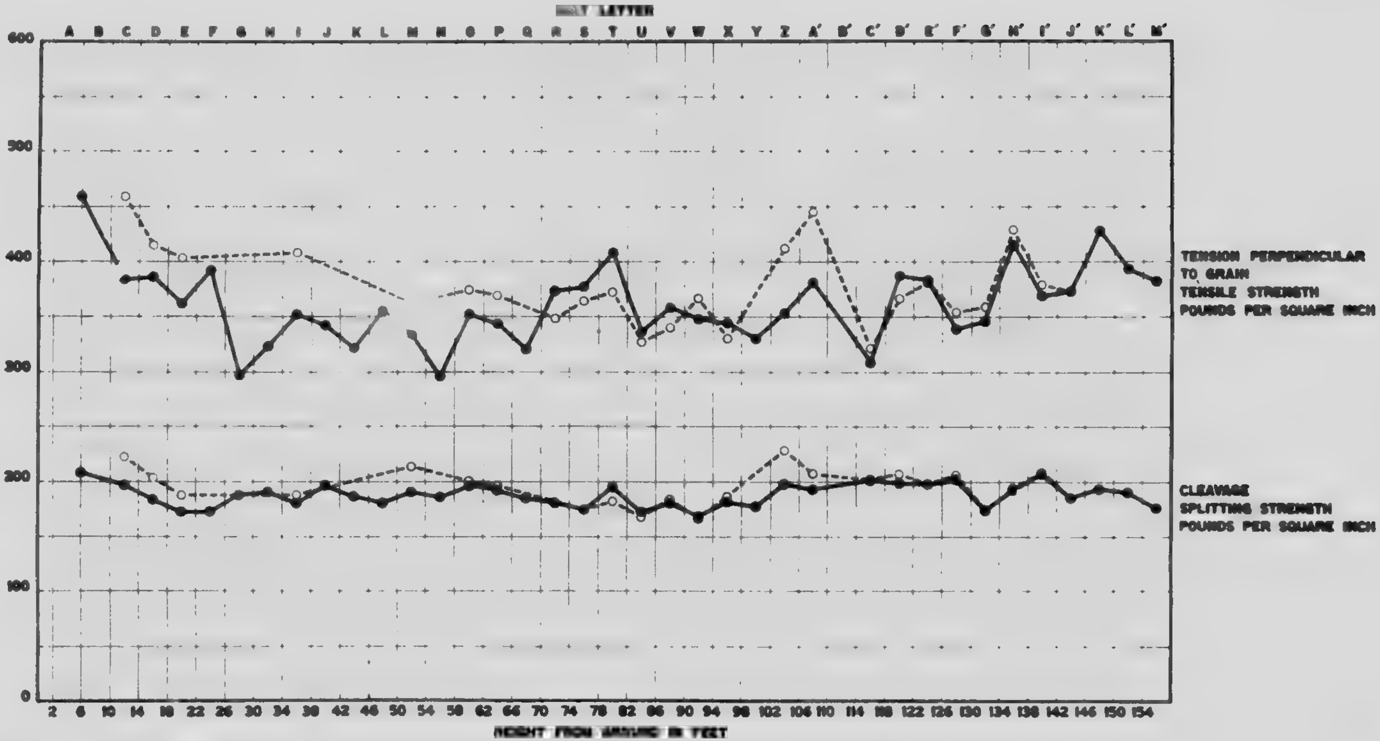


FIG. 37. – Curves showing variation of mechanical properties with height in tree (Tree 1, Shipment 2). – Tension perpendicular to grain and cleavage.

Full line shows averages for entire cross-section of tree, dotted line indicates averages for last 88 years' growth only.

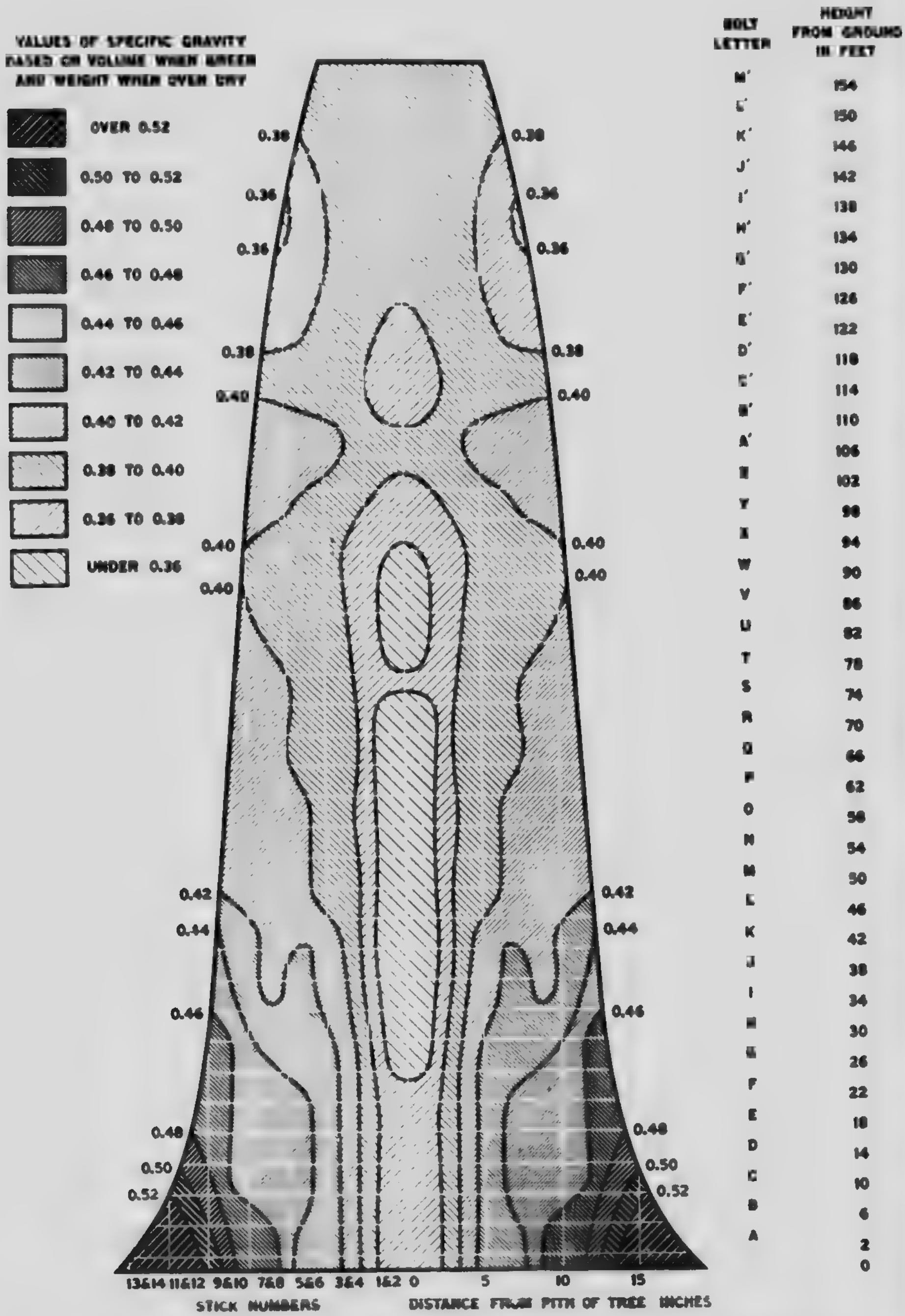


Fig. 38.—Diagram illustrating variation of properties throughout Tree 1, Shipment 2.—Specific gravity based on volume green and weight oven dry.

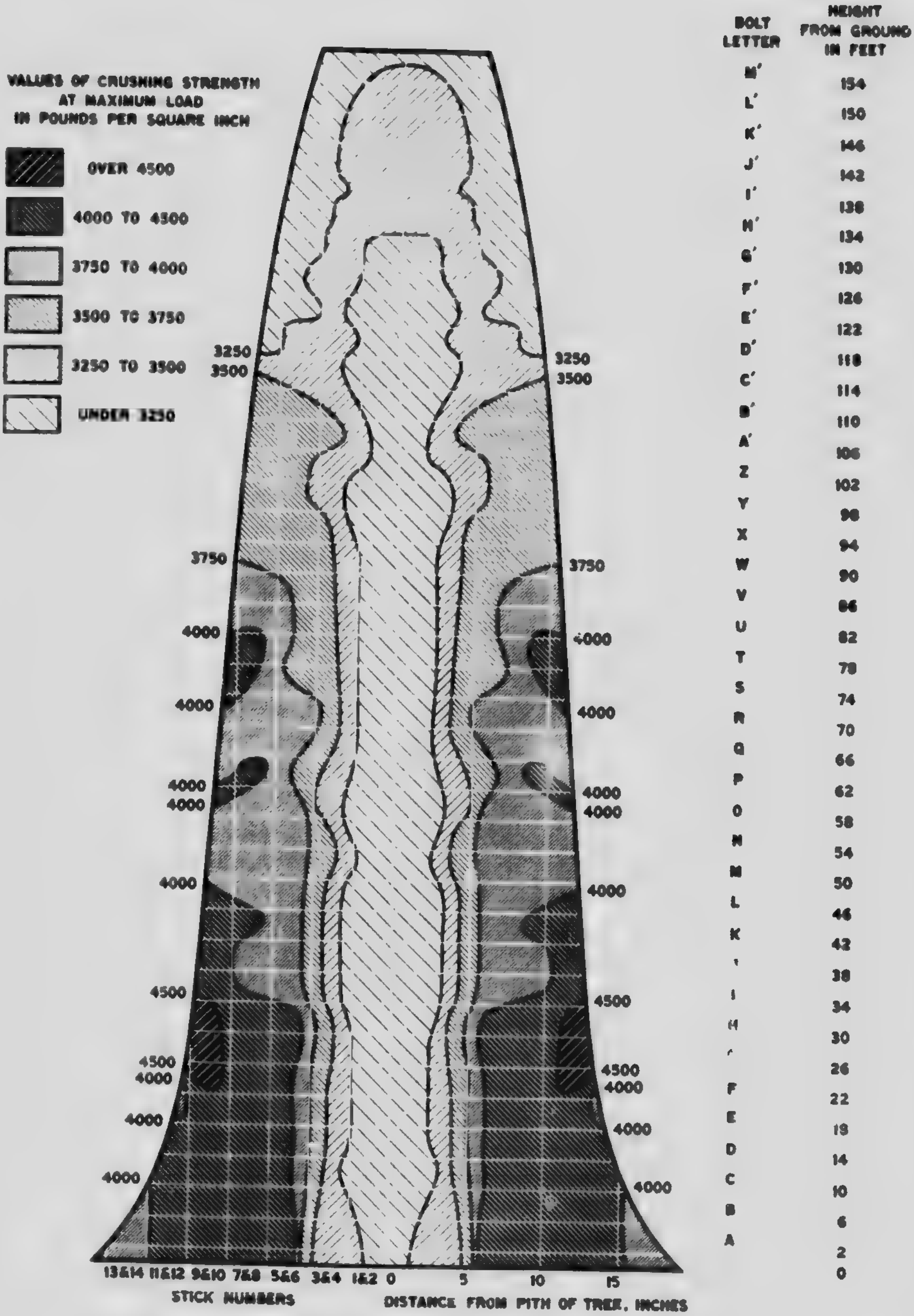


FIG. 39.—Diagram illustrating variation of properties throughout Tree 1, Shipment 2.—Maximum crushing strength in compression parallel to grain.

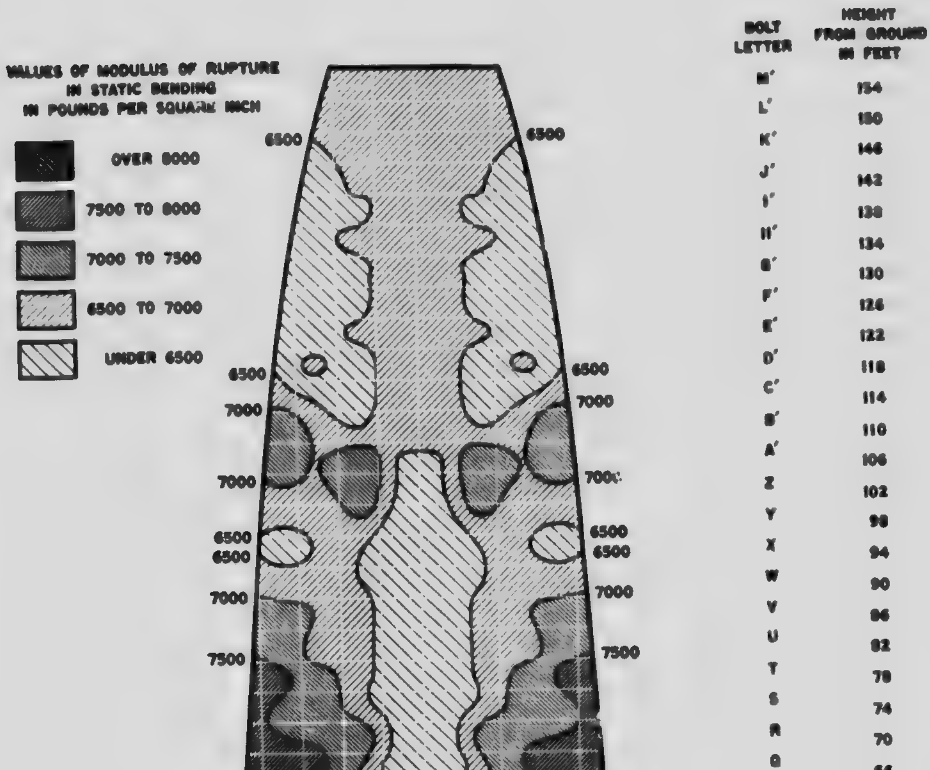


Fig. 40.—Diagram illustrating variation of properties throughout Tree 1, Shipment 2.—Modulus of rupture in static bending.

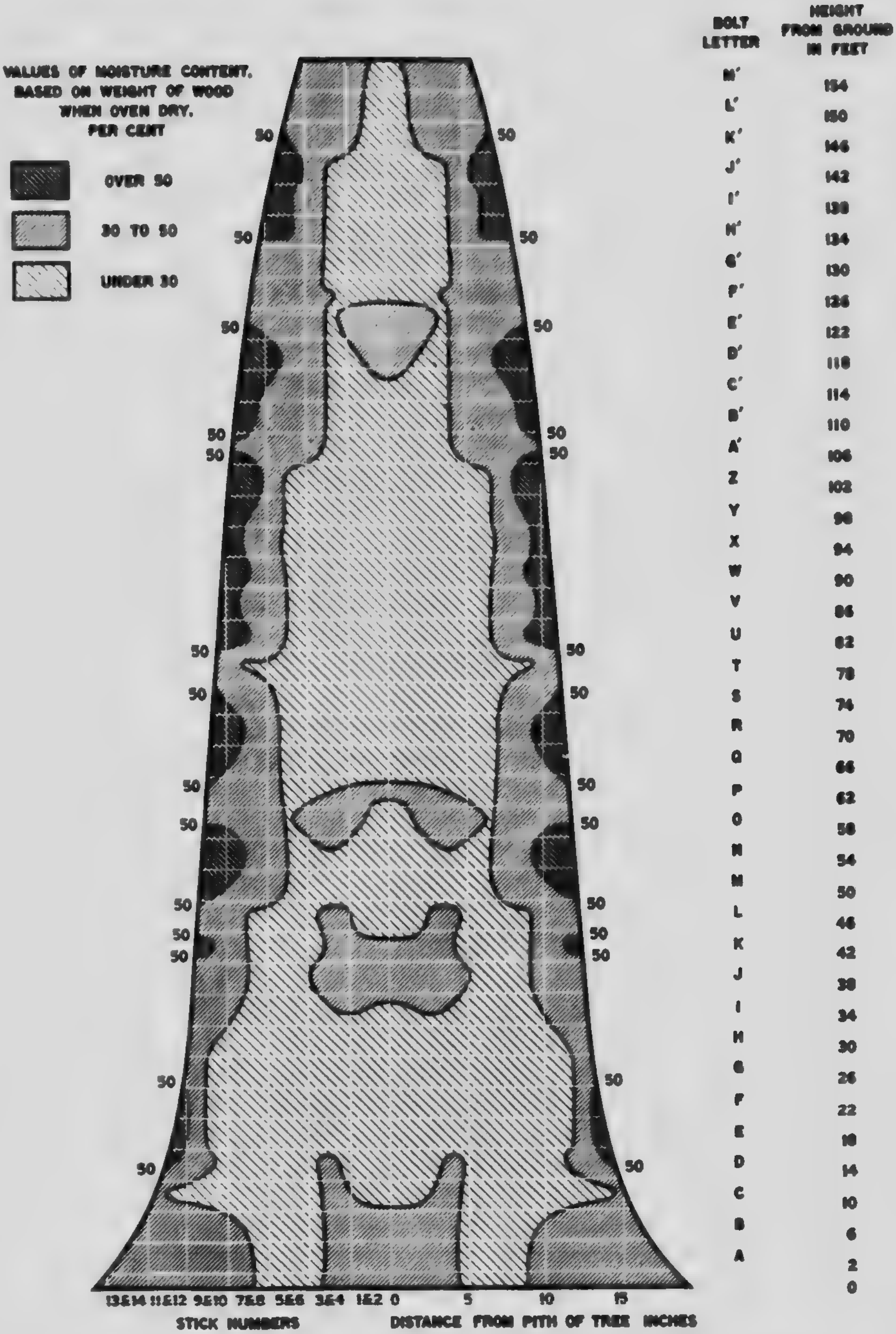


FIG. 41.—Diagram illustrating variation of properties throughout Tree 1, Shipment 2.—Moisture Content.

APPENDIX

OUTLINE OF PROGRAMME OF TESTS ON SPECIMENS FREE FROM DEFECTS

SCOPE OF INVESTIGATION.—This series of tests will be extended to include, eventually, all Canadian species of commercial importance. For each species material will be taken, ultimately, from as many localities as may be necessary to fairly represent variations of growth conditions occurring throughout the commercial range of that species, but until all the more important timbers have been investigated material for each species will be taken from one typical locality only. In the case of Douglas fir an exception to this rule was made in order to obtain at once more complete data regarding this very important timber species.

MATERIAL.—From each locality, for any species, five representative trees are taken. These trees, which are of commercial size and approximately average age, are identified in the forest by persons capable of determining the botanical species, full notes being made by the collector as to the conditions, in regard to soil, climate, and silvicultural considerations, under which the timber grew. From each tree one four-foot bolt is taken, usually the top four-foot bolt of the sixteen-foot butt log, these bolts providing material for tests to determine the average properties (in the green condition) of the wood of that species grown on that site.

The test sticks, as sawed, are of sufficient size to permit of finishing to 2 by 2 inches—the standard section of all test pieces cut from them. The other dimensions of these specimens are given below in connection with a detailed description of the various tests employed.

DETAILS OF TESTING METHODS.—The various mechanical tests and determinations of physical and structural properties employed, and the number of each made for every four-foot bolt, are as follows:

1. MECHANICAL TESTS

(1) Static Bending. One specimen from each of 50 per cent of the test sticks.[1]

(2) Impact Bending. Six specimens; two from near the heart, two from near the periphery, two from sticks of average growth.

(3) Compression parallel to grain. One specimen from every stick.

(4) Compression perpendicular to grain. One specimen from each of 25 per cent of the sticks.

(5) Hardness. One specimen from each of 25 per cent of the sticks.

(6) Shearing parallel to grain. Six specimens; two from a stick[2] near the heart, two from a stick near the periphery, two from a stick of average growth.

[1] *See* Fig. 42. One specimen is taken from each pair of sticks, by "pair" being meant any odd-numbered stick and the next higher even-numbered stick of the same direction in the tree. An even distribution of the specimens throughout the cross-section is thus secured.

[2] In all cases two specimens are taken from the same stick and prepared so as to give, one a radial, and one a tangential failure. ("Radial" or "tangential" to the rings of growth.)

(7) Cleavage. Six specimens; two from a stick near the heart, two from a stick near the periphery, two from a stick of average growth.

(8) Tension perpendicular to grain. Six specimens; two from a stick near the heart, two from a stick near the periphery, two from a stick of average growth.

2. DETERMINATIONS OF PHYSICAL AND STRUCTURAL PROPERTIES

(1) Moisture content. One determination made on every mechanical test specimen.

(2) Proportion of summer-wood (late wood). One determination for each stick.

(3) Rate of growth (rings per inch). One determination for each stick.

(4) Proportion of sapwood. One determination for each stick.

(5) Specific gravity and volumetric shrinkage. Six specimens[1]; two from near the heart, two from near the periphery, two from sticks of average growth.

(6) Linear shrinkage (radial and tangential to the growth-rings). Two specimens; one radial, one tangential.

The effect of air-drying upon mechanical and physical properties is investigated by testing specimens from two contiguous four-foot bolts from one tree, half the specimens being tested green, half after air-drying. (One of these two bolts is one of the five mentioned above, the other a sixth, additional bolt cut immediately adjoining it either above or below.)

The variation of properties with different positions in the tree is investigated by testing specimens cut from successive four-foot bolts comprising the entire merchantable length of one average tree, for each species.

All material is carefully marked by the collector and shipped to the laboratories in the log, the bark being left intact and the ends painted to prevent evaporation of moisture. It is found that material so treated can be kept in the green condition for considerable periods of time. At the laboratories the logs are cut up into test sticks as required for testing, in accordance with the scheme indicated in Fig. 42 which shows the standard sawing diagram as stencilled on the end of a log just before sawing. It will be noted that the sticks are taken two abreast along the north-south and east-west diameters, material representative of all conditions of growth throughout the log being in this way obtained. From the sector-shaped portions left after sawing in this way are cut specimens for the determination of linear skrinkage, and any other pieces that may be required for additional miscellaneous tests.

The methods followed in making these tests and determinations are described in detail in the following:—

MECHANICAL TESTS

TEST NO. 1. STATIC BENDING

Specimen.—Clear, straight-grained, 2 by 2 by 30 inches.
Testing Machine.—Universal, 30,000 lbs. capacity.

[1]Calculations of specific gravity are also made for all mechanical test specimens of tests Nos. 1, 2, 3, 4, and 5.

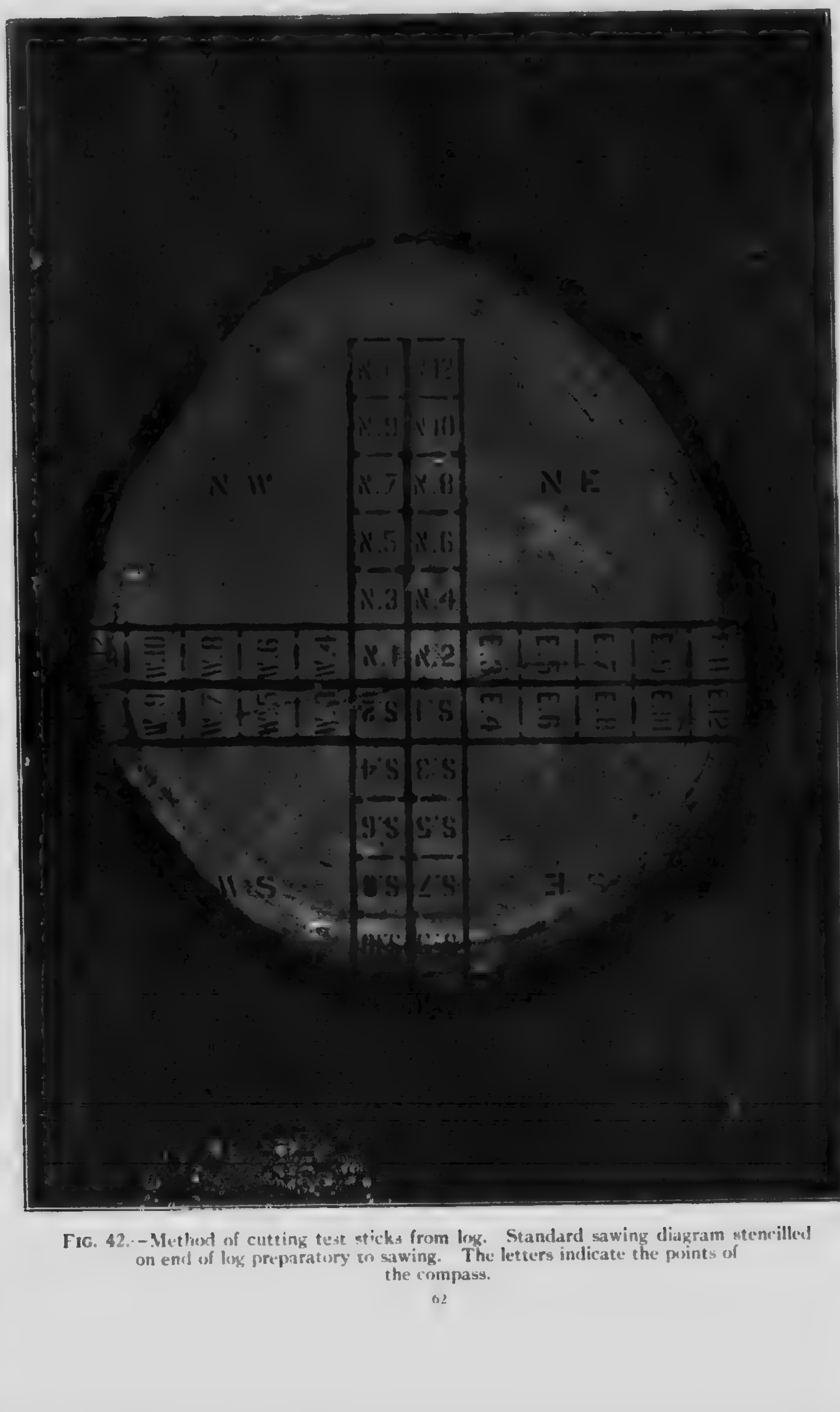


FIG. 42.—Method of cutting test sticks from log. Standard sawing diagram stencilled on end of log preparatory to sawing. The letters indicate the points of the compass.

Arrangement.—As shown in Fig. 43 the specimen is supported at the end on knife edges, on a span of 28 inches. Roller bearings between the plates upon which the ends of the specimen rest, and the knife edge supports, reduce end friction to a minimum. The knife edges bear against hardened steel seats, on supporting blocks, which rest upon a girder of steel "I" beams, and these in turn are carried on the weighing table of the testing machine.

Load is applied continuously through a wooden loading block at the centre point of the span, several thin steel plates being interposed between the bearing block and the specimen to reduce local crushing. The speed of descent of the loading head is 0·105 inch per minute.

In order to ensure uniformity of results all specimens are tested with radial surfaces vertical, heart side up.

Deformation.—Deflections at centre span are measured by a special deflectometer which is carried on small nails driven into the specimen on the neutral axis directly above the bearing points. The indicator of this deflectometer is supported, by means of a cord, from a small nail set in the specimen, on the neutral axis at mid-span. As the specimen bends the indicator drops, the amount of deflection being shown on the scale. Readings of deflection are taken to the nearest 0·01 inch, for each 100-pound increment of load, and a load-deflection curve plotted.

Results.—From the load-deflection curve the following quantities are obtained:

Measures of strength: Fibre stress at elastic limit, and modulus of rupture.

Measure of stiffness: Modulus of elasticity.

Measures of toughness: Work to elastic limit (elastic resilience), work to maximum load, and total work (to [illegible] deflection or failure to support 200-pound load).

Formulæ

Fibre stress at [illegible]

Modulus of rupture [illegible]

Modulus of elasticity $= \dfrac{P' L^3}{4 \Delta b h^3}$

Work to elastic limit $= \dfrac{P'}{2} \dfrac{\Delta}{bhL}$

Work to maximum load, and total work $= \dfrac{K \times \text{Area under load-deflection curve}}{bhL}$

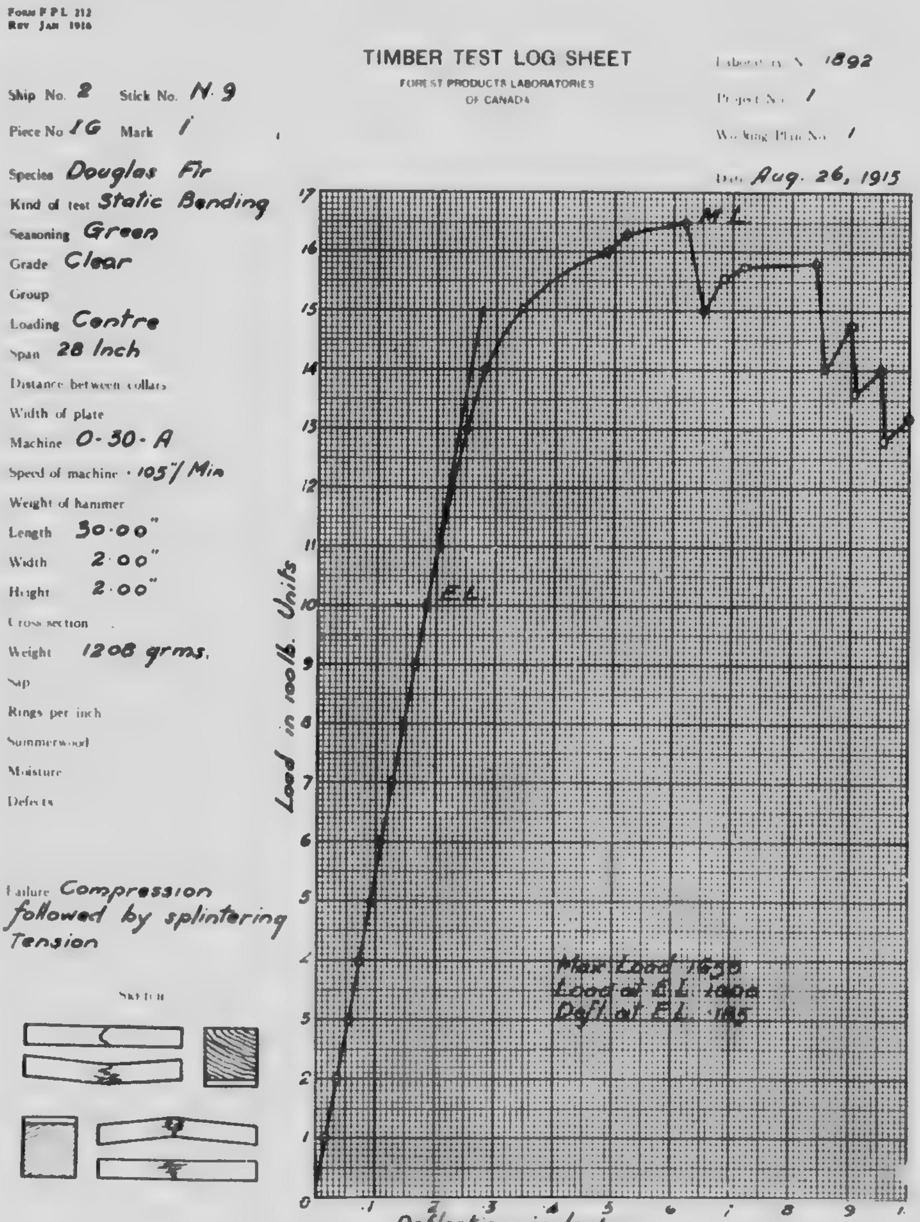
Where:—

P' = load at elastic limit.
P = maximum load.
Δ = deflection at elastic limit.
b = breadth of specimen.
h = height of specimen.
L = length of span.
K = a constant, varying with the scale used in plotting the curve.

FIG. 43.—Method of testing small clear specimens.—Static bending.

The area under the load-deflection curve to the point of maximum load, and to the point at which the specimen fails to support a 200-pound load or reaches a deflection of 6 inches, is measured by planimeter.

A typical load-deflection diagram for this test is shown in Fig. 14.


Form F.P.L. 212
Rev. Jan. 1916

TIMBER TEST LOG SHEET

FOREST PRODUCTS LABORATORIES
OF CANADA

Laboratory No. 1892

Project No. 1

Working Plan No. 1

Date Aug. 26, 1915

Ship No. 2 Stick No. N. 9

Piece No. 1G Mark 1

Species Douglas Fir

Kind of test Static Bending

Seasoning Green

Grade Clear

Group

Loading Centre

Span 28 Inch

Distance between collars

Width of plate

Machine O-30-A

Speed of machine ·105"/Min

Weight of hammer

Length 30·00"

Width 2·00"

Height 2·00"

Cross section

Weight 1208 grms.

Sap

Rings per inch

Summerwood

Moisture

Defects

Failure Compression followed by splintering Tension

Sketch

Fig. 14.—Typical load deflection diagram.—Static bending.

TEST NO. 2. IMPACT BENDING

Specimen.—Clear, straight-grained, 2 by 2 by 30 inches.

Testing Machine.—Hatt-Turner impact machine, 50-, 100-, and 250-pound hammers.

Arrangement.—The specimen is supported at the ends, on a span of 28 inches, through bearing-plates on " V " blocks which rest on the bed of the machine.

Load is applied by dropping the loading-hammer upon the specimen at mid span, the first drop being from a height of one inch, and succeeding drops from heads increasing by 1-inch increments up to 10 inches. Thereafter drops are made at successive increments of 2 inches, until failure.

Deformations.—Deflections of the specimen under load and precise heights of fall for the earlier drops are measured from a drop curve traced on the recording drum by a pencil secured in the hammer. A curve of deflections squared, against corresponding heights of drop or head, is plotted from measurements of the autographic drop tracings.

Results.—From the " head-deflection-squared" curve, and the data observed during the test, the following quantities are obtained:—

Measure of strength under impact loading: fibre stress at elastic limit.

Measures of toughness: Height of drop at failure, and work to elastic limit.

Measure of stiffness: Modulus of elasticity.

Formulæ.—

$$\text{Fibre stress at elastic limit} = \frac{3\ WH'L}{\Delta bh^2}$$

$$\text{Modulus of elasticity} = \frac{L^2 \times \text{F.S. at E.L.}}{6\Delta h}$$

$$\text{Work to elastic limit} = \frac{WH'}{bhL}$$

Where:—

W = weight of hammer.

H′ = height of drop at elastic limit.

Δ = central deflection of specimen at elastic limit.

F.S. at E.L. = fibre stress at elastic limit.

b = breadth of specimen.

h = height of specimen.

L = span.

Fig. 46 shows a typical autographic curve as traced by the pencil in the drop hammer upon the recording drum. The movements of the hammer can be accurately traced by following the curve. Note the initial drop followed by considerable deflection of the specimen, and rebound of the hammer, and successively decreasing deflections and rebounds until the hammer finally comes to rest. Succeeding drops show a permanent set of the specimen (in part due to bruising of the upper surface at point of impact) setting in, and gradually increasing. The horizontal " base line " is drawn when the hammer is at rest

FIG. 45.—Method of testing small clear specimens.—Impact bending.

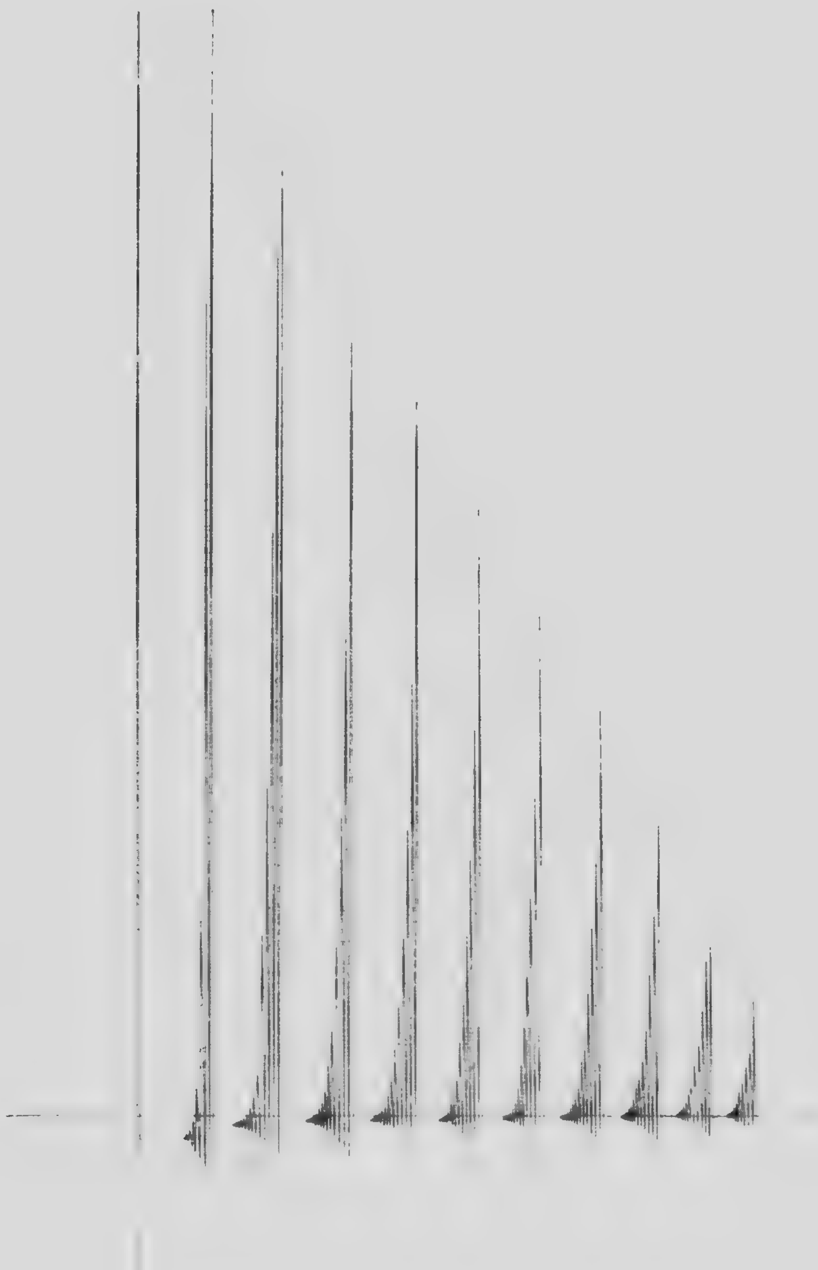


FIG. 16.—Typical autographic curve traced by drop hammer. Impact bending.

upon the specimen before the test is begun. Finally, the hammer drops through the specimen, which is completely broken by the blow.

In Fig. 47 is shown a typical "head-deflection-squared" curve as plotted from measurements of the autographic curve.

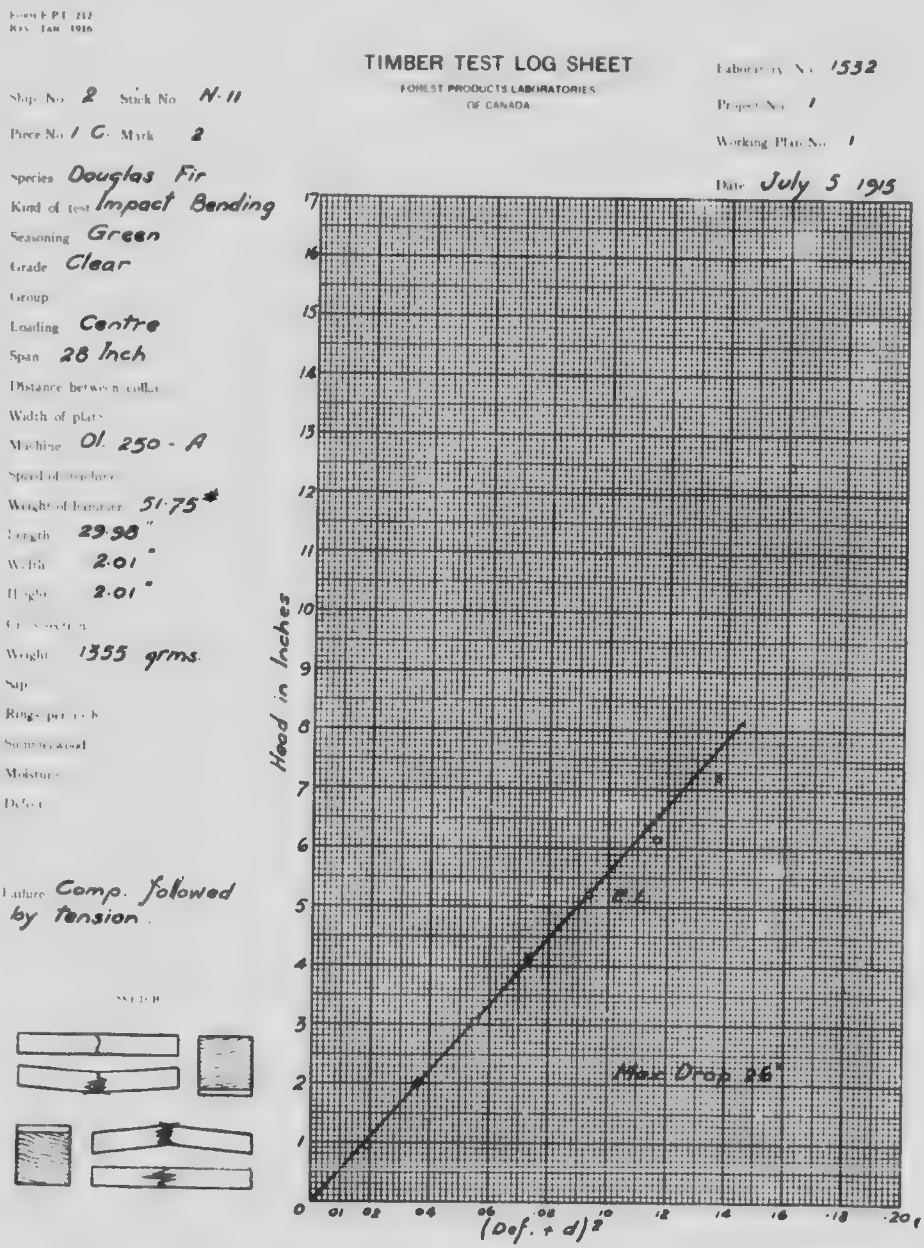


FIG. 47.—Typical head-deflection-squared curve.—Impact bending.

TEST NO. 3 — COMPRESSION PARALLEL TO GRAIN

Specimen.—Clear, straight-grained, 2 by 2 by 8 inches. Ends carefully squared.

Testing Machine.—Universal, 30,000 or 60,000 pounds capacity.

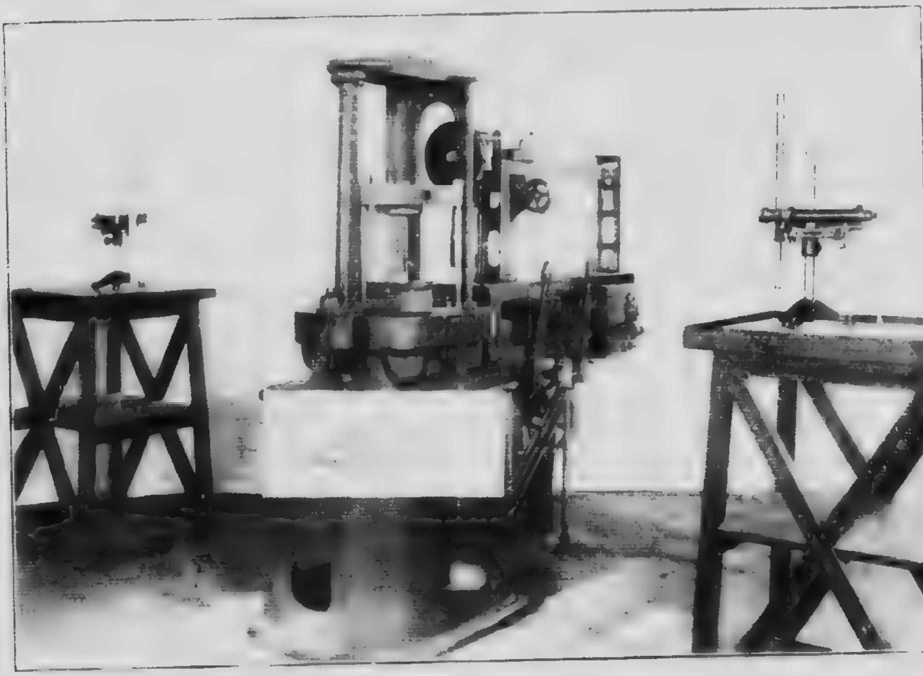


Fig. — Method [illegible] compression parallel to grain [illegible]

[illegible] block provided with a ball-and-socket [illegible] load, this in turn resting on the [illegible]. The loading head of the testing machine [illegible] the specimen through a flat platen. Load [illegible] ing head being 0·024 inch [illegible].

[illegible] are measured [illegible] modified Martens reflecting mirror [illegible] gauge length [illegible]. Two instruments are used, [illegible] specimen. The instruments, [illegible] are read to the nearest 0·0001 inch for [illegible] the testing machine with [illegible] in place [illegible] the scales and the telescopes through which [illegible] shows [illegible] view of the specimen, bearing-[illegible] been completed the readings of [illegible] deflection curve plotted.

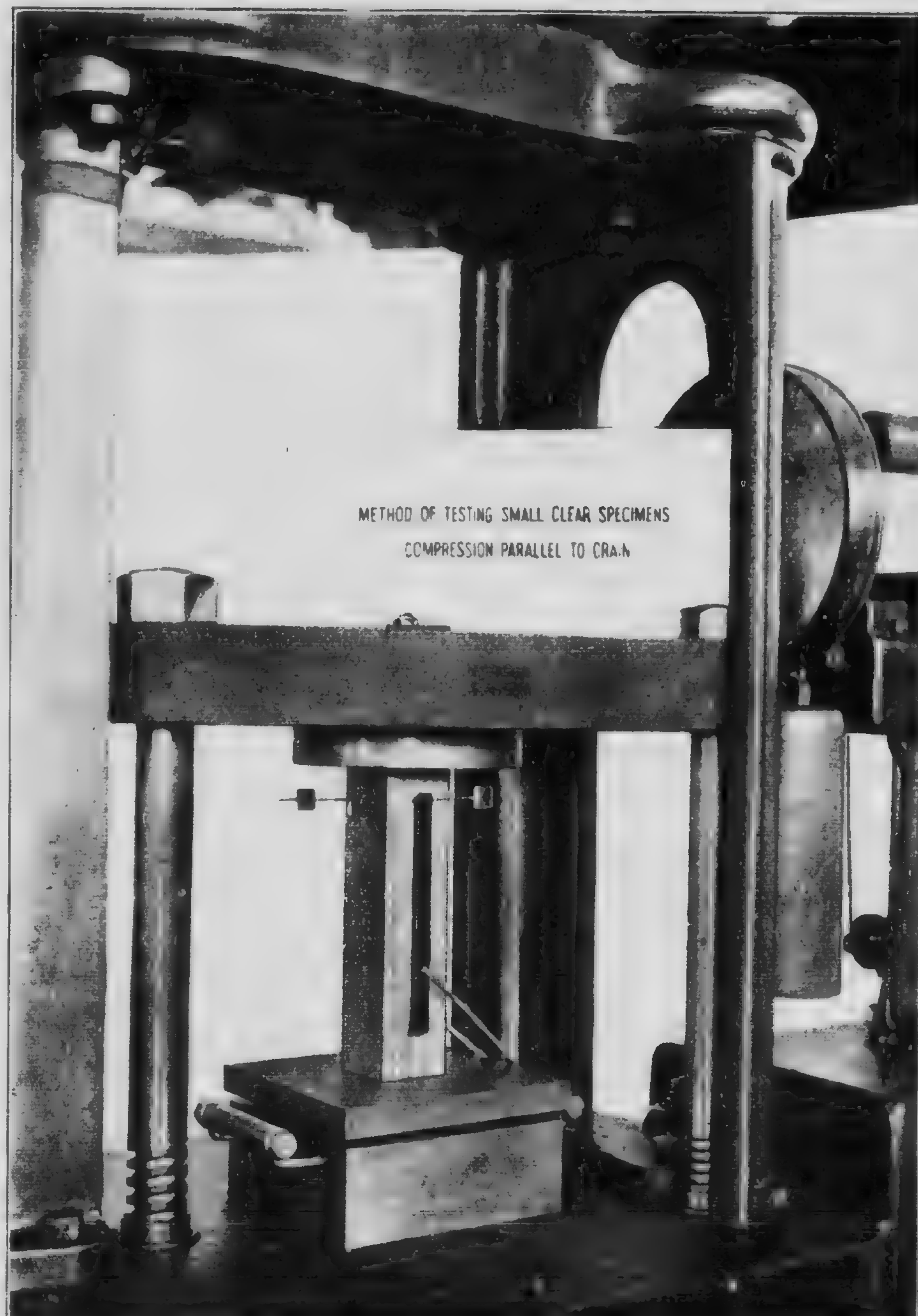


FIG. 49.—Method of testing small clear specimens.—Compression parallel to grain.

Near view showing specimen, bearing-blocks, and modified Martens mirror compressometers.

28743 6½

Results.—From the load-deflection curve are obtained:

Measures of strength: Compressive stress at elastic limit, and crushing strength at maximum load.

Measure of stiffness: Modulus of elasticity.

A typical load-deflection curve for this test is shown in Fig. 50.

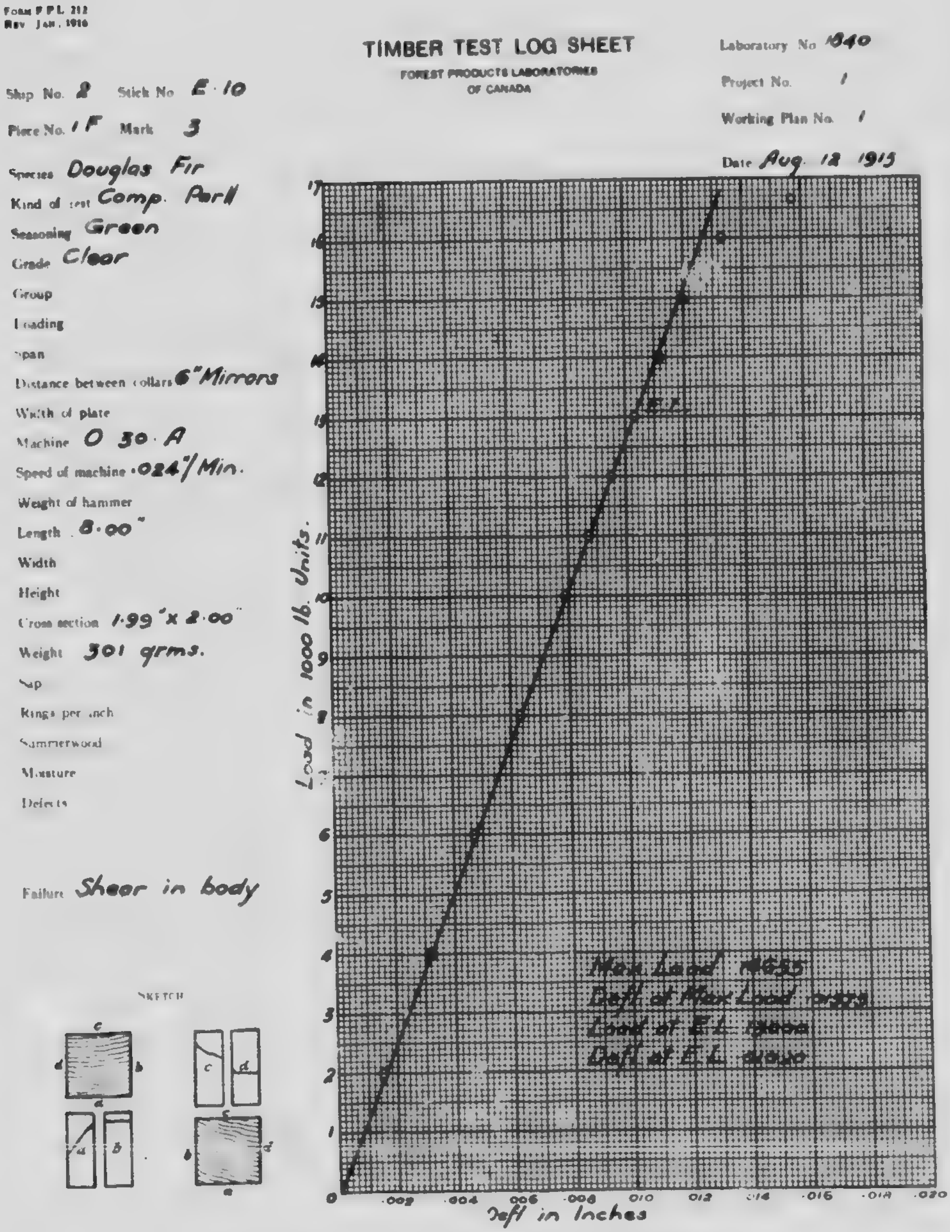


FIG. 50. Typical load deflection diagram.—Compression parallel to grain.

Formulæ.—

$$\text{Compressive stress at elastic limit} = \frac{P'}{bh}$$

$$\text{Crushing strength at maximum load} = \frac{P}{bh}$$

$$\text{Modulus of elasticity} = \frac{L'P'}{bh\Delta}$$

Where:

P' = load at elastic limit.
P = total crushing load.
L' = length over which compressions are measured.
b and h = dimensions of specimen cross-section.
Δ = compression at elastic limit

TEST NO. 4. COMPRESSION PERPENDICULAR TO GRAIN

Specimen.—Clear, straight-grained, 2 by 2 by 6 inches.
Testing Machine.—Universal, 30,000 pounds capacity.

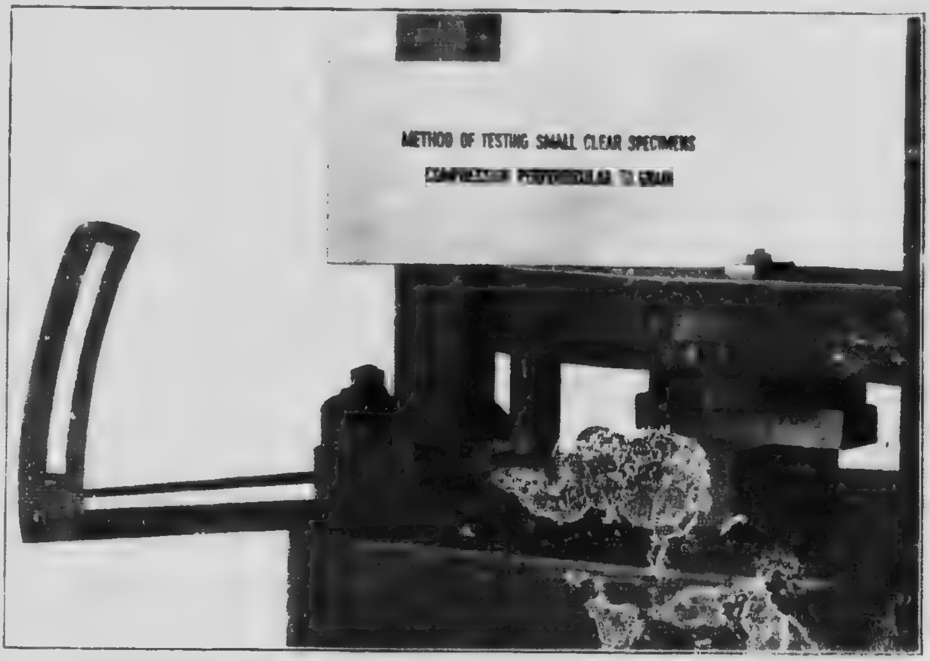


FIG. 51. Method of testing small clear specimens.—Compression perpendicular to grain

Arrangement.—The specimen is carried directly on the weighing table of the testing machine. Load is applied continuously to a radial surface of the specimen from the loading head of the testing machine through a plate 2 inches in width and of length greater than the width of the specimen. The rate of descent of the loading head is 0·024 inch per minute.

Deformations. Deformations of the specimen are measured by a deflectometer, the lever arm of which bears against the loading platen. Readings are taken to the nearest 0·001 inch for each 250-pound increment of load until

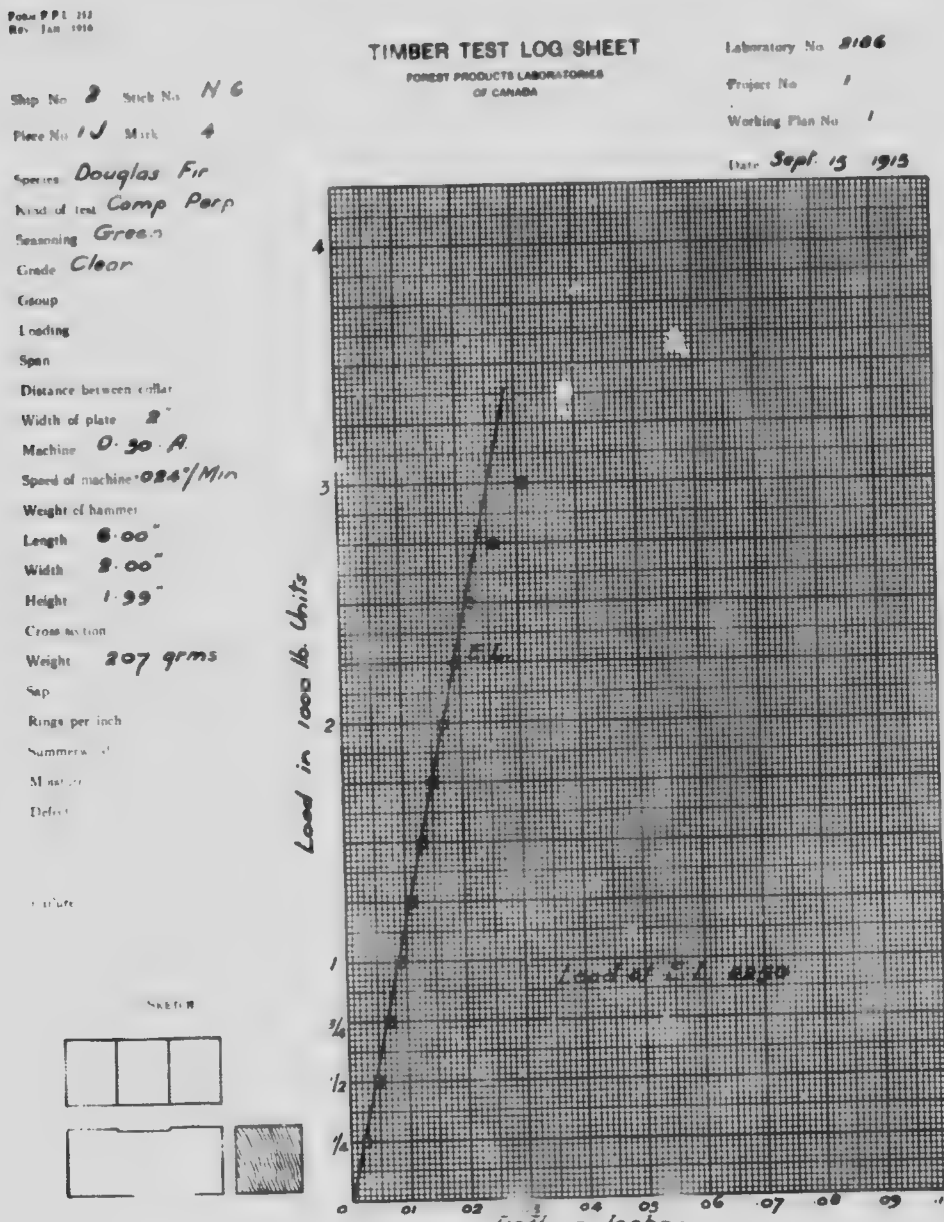


Fig. 52. Typical load deflection diagram.—Compression perpendicular to grain.

the total deformation is 0·1 inch, a load-deflection curve being plotted as the test proceeds.

Results.—The compressive stress at elastic limit (per square inch of area under loading plate) is calculated from the load at elastic limit, as determined from the load-deflection curve.

Fig. 52 shows a typical load-deflection curve as plotted for this test.

TEST NO. 5. HARDNESS

Specimen.—Clear, straight-grained, 2 by 2 by 6 inches.

Testing Machine.—Universal, 30,000 pounds capacity.

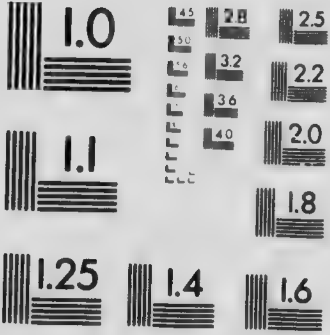
FIG. 53.—Method of testing small clear specimens.—Hardness.

Arrangement.—The specimen rests directly on the weighing table of the testing machine, the hardness test-tool, a steel bar with hemispherical end of 0·444 inch diameter (1 square centimeter projected area) being fixed in the loading head of the machine. The penetration of the hemispherical end of the bar is limited to 0·222 inch by a cup-shaped washer, through a hole in the bottom of which it protrudes. The load at the instant of complete penetration, as determined by the binding of the washer between the end of the steel bar and the specimen, is taken to be a measure of the hardness. Two penetrations are made on one tangential, two on one radial, and one on each end surface. The constant rate of descent of the loading head is 0·25 inch per minute.

Fig. 53 shows the general arrangement of the test-tool and the specimen.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



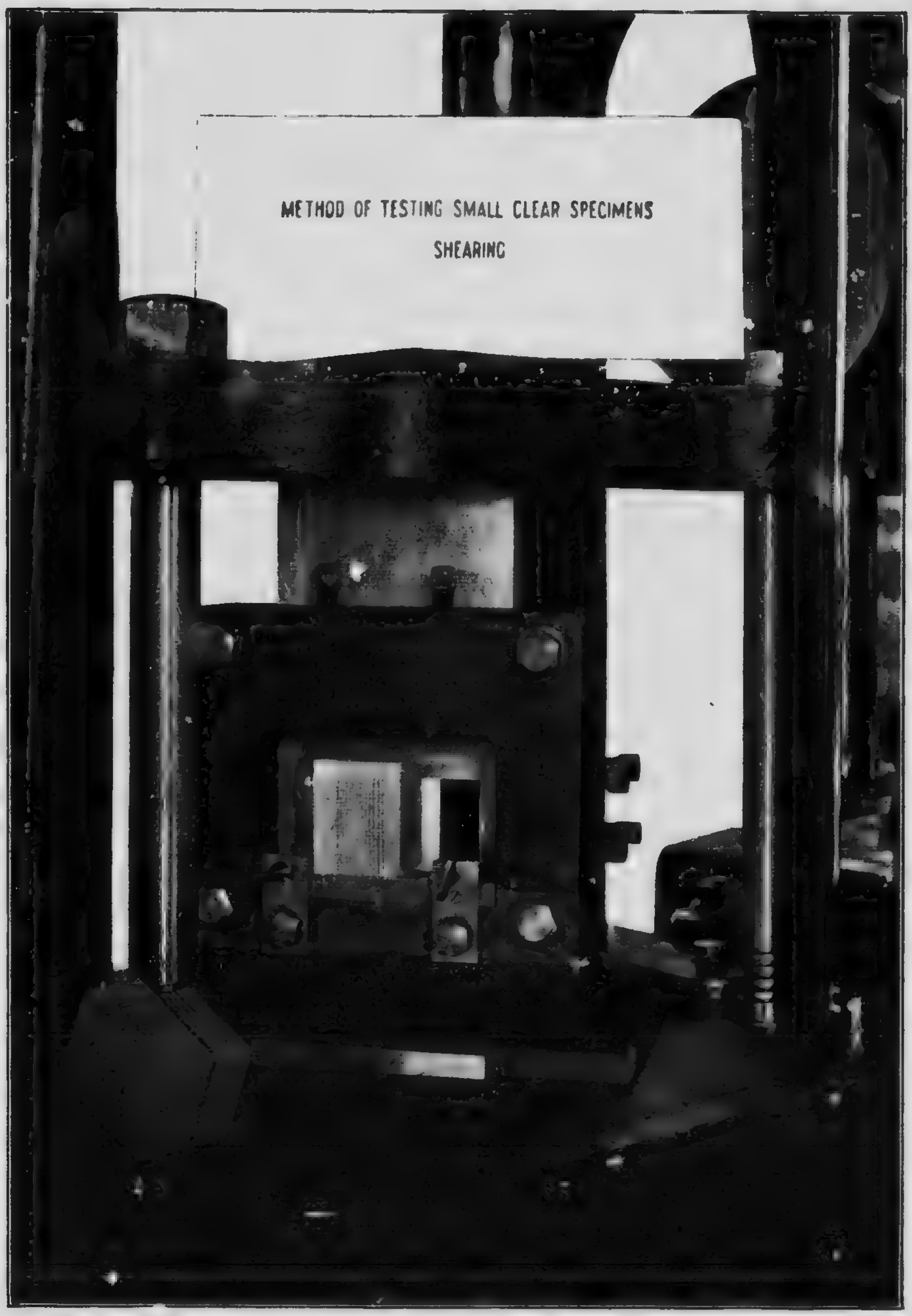


FIG. 54.—Method of testing small clear specimens.—Shearing parallel to grain.

TEST NO. 6. SHEARING PARALLEL TO GRAIN

Specimen.—Clear, straight-grained, 2 by 2 inches in section, 2½ inches long. A ½ by ½ inch check is cut in the top end along one edge, leaving a projecting shoulder on the specimen.

Machine.—Universal, 30,000 pounds capacity.

Arrangement.—The specimen is placed in a shearing block which rests directly on the weighing table of the testing machine. A shearing plate which slides in a groove in the shearing block is fixed in the loading head of the machine, and bears against the projecting shoulder of the specimen. The specimen in the shearing block rests on a steel plate, the edge of which clears the groove of the shearing plate by ⅛ inch, and is backed by a plate with adjusting screws to hold it in position. [This plate has been removed in the illustration in order to show the specimen more clearly.] The speed of descent of the loading head is 0·015 inch per minute.

Results.—The maximum load is observed and the maximum shearing strength calculated therefrom. The direction of the failure[1] (whether radial or tangential with respect to the rings of growth) is noted, and results are classified accordingly.

TEST NO 7. CLEAVAGE

Specimen.—Clear, straight-grained, 2 by 2 by 3¾ inches, cut across one end to a depth of ¾ inch by a circular hole 1 inch in diameter (centre ¼ inch from end of specimen), leaving a net splitting length of three inches.

Machine.—Universal, 30,000 pounds capacity.

Arrangement.—The specimen is held in two special grips which are secured, one in the loading head and one in the upper weighing head of the testing machine. The end of the specimen butts against the inner face of the grips, the line of pull thus being a constant distance from the end of the specimen, and from the line of maximum stress (former distance ¼ inch, latter ½ inch). Fig. 55 shows the arrangement of the apparatus.

The speed of descent of the loading head is 0·25 inch per minute.

Results.—The load at failure is observed and the splitting strength per inch of width of specimen calculated therefrom. The direction of the failure[1] (whether radial or tangential with respect to the rings of growth) is noted, and results are classified accordingly.

TEST NO. 8. TENSION PERPENDICULAR TO GRAIN

Specimen.—Clear, straight-grained, 2 by 2 inches section, 2½ inches long, cut across both ends to a depth of ¾ inch by circular holes 1 inch in diameter (centres ¼ inch from ends of specimen), leaving a net breaking area of 1 by 2 inches.

Arrangement.—The specimen is held in two special grips which are secured, one in the loading head and one in the upper weighing head of the testing machine.

[1]In the case of shearing, cleavage and tension perpendicular to grain tests two specimens are in every case taken from the same test stick and prepared so as to give, one a radial failure and one a tangential failure.

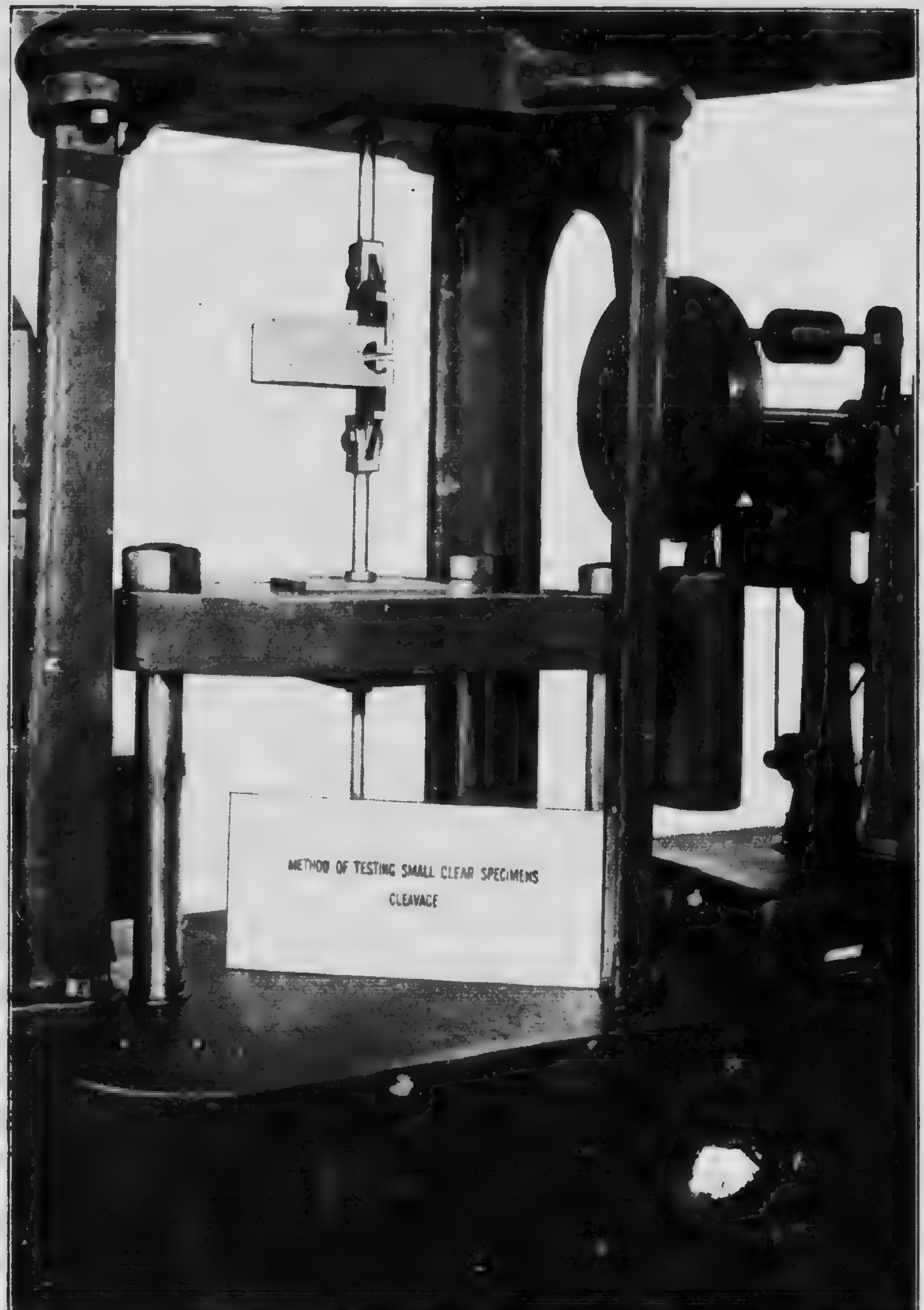


FIG. 55.—Method of testing small clear specimens.—Cleavage.

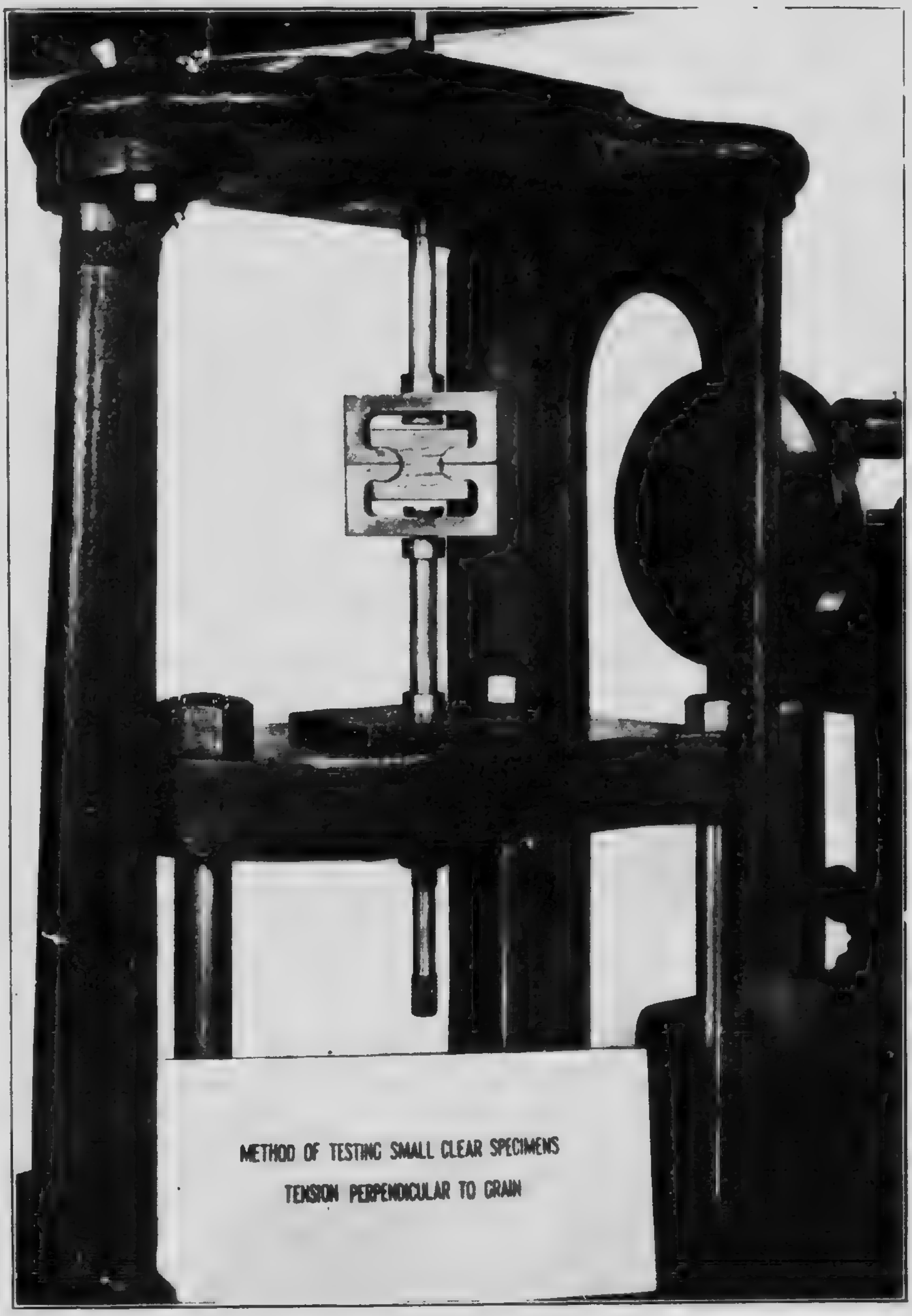


FIG. 56.—Method of testing small clear specimens.—Tension perpendicular to grain.

Ball-and-socket bearings permit of slight adjustments of the grips to compensate for any inaccuracies in the preparation of the specimen and to ensure uniform distribution of the load. The speed of descent of the loading head is 0·25 inch per minute.

Results.—The breaking load is observed and the tensile strength perpendicular to the grain calculated therefrom. The direction of failure, (whether radial or tangential with respect to the rings of growth) is noted, and results are classified accordingly.

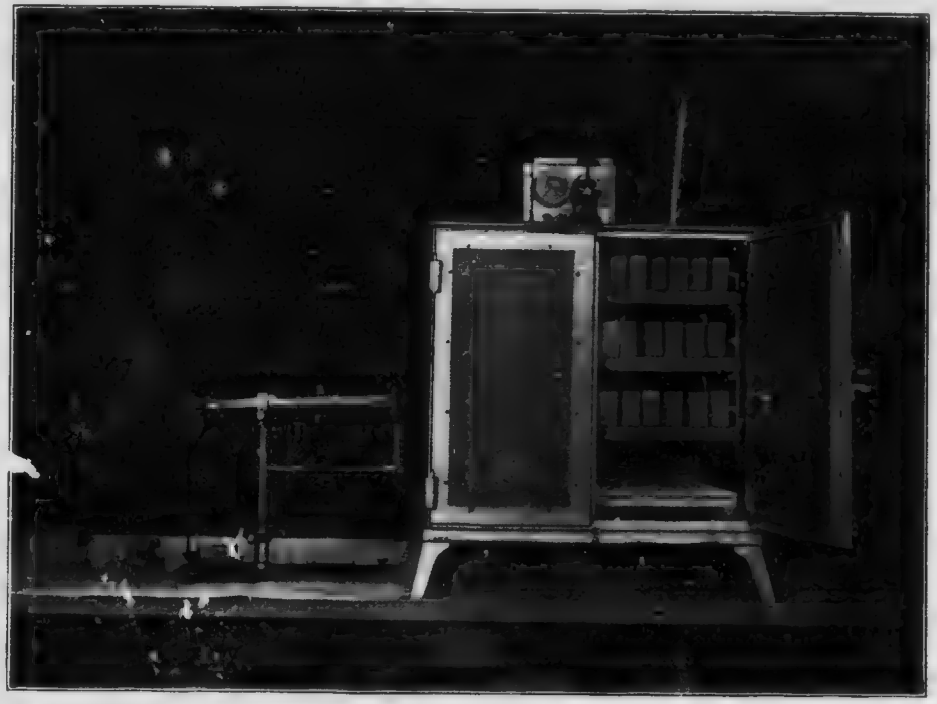


FIG. 57.—Drying oven and balance used in making moisture determinations.

DETERMINATIONS OF PHYSICAL AND STRUCTURAL PROPERTIES

DETERMINATION 1.—MOISTURE CONTENT

Specimen.—Special discs for the determination of moisture content are cut from all mechanical test pieces after test. In the case of shear, cleavage, and tension tests these consist of irregular portions split off adjacent to the failure. From all other test pieces a disc 1 inch in length and of the full section of the specimen is sawed out from a point near the failure. Typical moisture discs for the various mechanical tests are shown in Fig. 57.

Procedure.—Discs are weighed, immediately after they are cut, to the nearest 0·1 gram, dried to constant weight in an oven at 100° C, and again weighed. Moistures are calculated as percentages of the oven-dry weight of the wood.

Electric ovens are employed for drying the discs. (See Fig. 57).

DETERMINATIONS 2, 3 AND 4.—RINGS PER INCH, PERCENTAGE OF SUMMER-WOOD, AND PERCENTAGE OF SAPWOOD

Specimen.—Estimations of rings per inch, percentage of summer-wood, and percentage of sapwood are made on the discs cut for the determination of moisture content, as described above.

Procedure.—A line 1 inch in length is drawn on the cross-section of the disc in a radial direction so as to pass through a region of average development. The total width of summer-wood crossed by this line is estimated by spacing off accumulatively, on a pair of dividers, the width of the summer-wood band for each growth-ring in succession. The distance between the points of the dividers on the completion of this operation for the measured inch length, in hundredths of an inch, equals numerically the percentage of summer-wood.

The number of rings per inch is determined simultaneously with the estimation of summer-wood by noting the number of growth-rings crossed by the measured inch.

The amount of sapwood (if any) present in the stick is estimated by calculating the amount of the cross-section area of the disc in which sapwood appears, and expressing this as a percentage of the total area.

DETERMINATION 5.—SPECIFIC GRAVITY AND VOLUMETRIC SHRINKAGE

Specimen.—Clear, 2 by 2 by 6 inches.

Procedure.—Determinations of specific gravity and volumetric shrinkage are made when the specimen is in the green, the air-dry, and the oven-dry conditions.

Specific gravities are determined by calculating the ratio of the weight of the specimen to the weight of an equal volume of water. The former quantity is obtained directly in the usual manner, the method of determining the latter is as follows:

A vessel containing water is mounted on one scale-pan of a balance, and the balance is brought into equipoise by suitably counterbalancing with lead shot. The specimen held impaled on the point of a light steel rod is then completely immersed in the water, care being taken that no water overflows the container and that the specimen does not touch the vessel at any point, and the balance is again restored to equilibrium by adding standard weights to the opposite scale-pan. The weight required to restore the balance in this way is the weight of a volume of water equal to the volume of the specimen. If expressed in grams it is also numerically equal to the volume of the specimen expressed in cubic centimeters. The specimen when in the oven-dry condition is dipped in paraffine before immersing in water. The arrangement of the apparatus made use of is shown in Fig. 58.

Volumetric shrinkage figures, based on volumes determined as explained above, are expressed as percentages of the volume when green.

Calculations of the specific gravities of all mechanical test pieces which are complete prisms in shape are also made on the basis of the weight and dimensions of these specimens, as determined in connection with the mechanical tests. These specific gravity figures are expressed both in terms of the

FIG. 58.—Method of testing small clear specimens.—Specific gravity and volumetric shrinkage.

weight of the specimen as tested and of the weight oven-dry, but in both cases the volume used is the volume at the time the mechanical tests were made.[1]

DETERMINATION 6.—LINEAR SHRINKAGE

Specimen.—Clear, 1 by 1 by 4 inches, the long dimension in the direction in which the shrinkage is to be measured, either radial or tangential to the growth-rings.

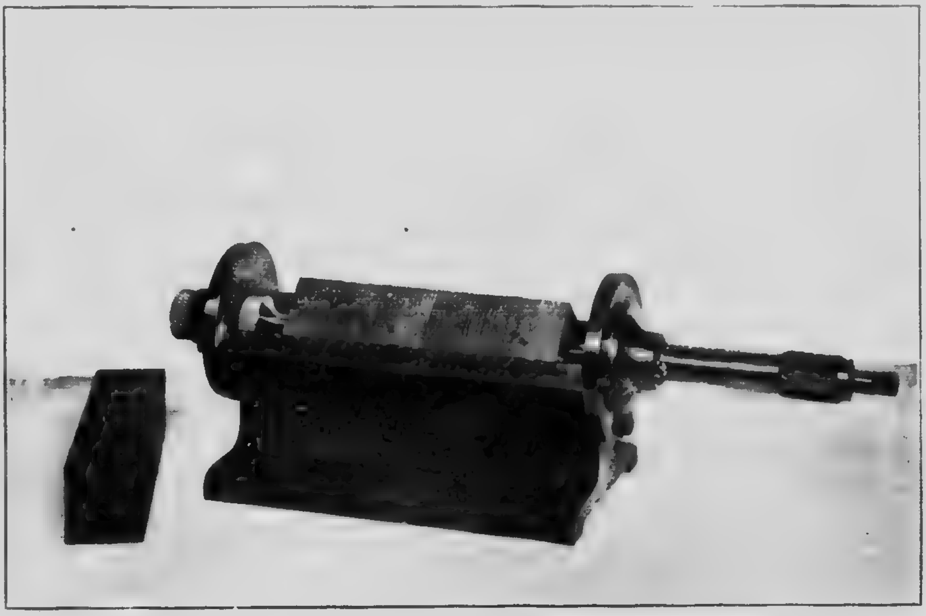


FIG. 59.—Method of testing small clear specimens.—Determination of linear shrinkage.

Procedure.—The length of the specimen in the green, the air-dry, and the oven-dry condition is measured to the nearest 0·001 inch by means of the special micrometer gauge shown in Fig. 59. Shrinkages are expressed as percentages of the green dimensions.

[1]Statements of the specific gravity of wood are considerably complicated owing to the consideration that the two factors (viz.: weight and volume) upon which specific gravities are based are, in the case of this substance, both variables depending upon the moisture content. Weight of wood, of course, varies directly with the moisture content. The volume is a constant for all moistures above a certain critical value (the fibre saturation point), but when the moisture is decreased below this value shrinkage takes place and the volume decreases progressively as the wood becomes drier. Specific gravity figures for wood are, therefore, meaningless unless the conditions as to moisture content under which they apply are specified.

Specific gravities determined by the water displacement method described above are strictly correct, being the ratio of the weight of the wood to the weight of an equal volume of water at various stages of the seasoning process. Of the two specific gravity figures determined in connection with the mechanical tests, that based on volume and weight as tested, is also quite correct. The specific gravity "based on volume green and weight oven-dry" is, however, not in reality a true specific gravity at all, being based on volumes and weights which could never occur simultaneously for the specimen in question.

It is, however, a very useful figure, inasmuch as true specific gravities can be calculated from it with perfect accuracy for timber at any moisture content above the fibre saturation point (green timber), and with fair accuracy for moisture contents between the fibre saturation point and the air-dry condition, simply by increasing it by a percentage corresponding to the moisture content in question. In this respect this apparently anomalous figure is of more practical use than certain strictly correct values of the specific gravity which are of significance only for the moisture content at which they were determined.

BIBLIOGRAPHY

Other publications containing data regarding the properties and characteristics of Douglas fir:

"Properties and Uses of Douglas Fir." United States Dept. of Agriculture, Forest Service Bulletin 88. McGarvey Cline and J. B. Knapp. Pp. 5. Pls. III. Diagrams 15. Tables 15. Washington, 1911.

"Fire-killed Douglas Fir—A Study of its Rate of Deterioration, Usability and Strength." United States Department of Agriculture, Forest Service—Bulletin 112. J. B. Knapp. Pp. 18. Figs. 5. Washington, 1912.

"Douglas Fir—A Study of the Pacific Coast and Rocky Mountain Forms." United States Department of Agriculture, Forest Service—Circular 150. E. H. Frothingham. Pp. 38. Ills. 3. Washington, 1909.

"Tests of Structural Timbers." United States Department of Agriculture, Forest Service—Bulletin 108. McGarvey Cline and A. L. Heim. Pp. 123. Pls. VII. Figs. 29. Tables 15. Washington, 1912.

"Strength Values for Structural Timbers." United States Department of Agriculture, Forest Service—Circular 189. McGarvey Cline. Pp. 8. Tables 4. Washington, 1912.

"Strength Tests of Structural Timbers Treated by Commercial Wood-Preserving Processes." United States Department of Agriculture—Bulletin 286. H. S. Betts and J. A. Newlin. Pp. 15. Tables 3. Figs. 7. Washington, 1915.

"Tests of Douglas Fir Bridge Stringers—Comparative Test of Treated and Untreated Douglas Fir Stringers to Determine the Effect of Treatment on Physical Properties." H. B. McFarland. Bulletin of the American Railway Engineering Association. Vol. 17. No. 184. February 1916. Pp. 281-467. Figs. 153. Tables 11.

"Test of Oregon Fir Piling—Comparative Tests on Treated and Untreated Oregon Fir Piling to Determine the Effect of Treatment Upon Physical Properties." H. B. McFarland. Bulletin of the American Railway Engineering Association. Vol. 16. No. 168. August 1914. Pp. 47-150. Tables 12. Figs. 75.

"Creosoting Douglas Fir Bridge Stringers without Loss of Strength." O. P. M. Goss. Association of Creosoting Companies of the Pacific Coast. Pp. 27. Diagrams 9. Tables 7. Seattle, 1916.

"Canadian Woods for Structural Timbers." Department of the Interior, Canada, Forestry Branch—Bulletin 59. H. N. Lee. Pp. 44. Pls. XIX. Figs. 3. Tables 5. Ottawa, 1917. Free upon application.

"Mechanical Properties of Woods Grown in the United States." United States Department of Agriculture—Bulletin 556. J. A. Newlin and Thomas R. C. Wilson. Pp. 47. Tables 3. Pls. III. Washington, 1917.

TABLE 10. VARIATION OF MECHANI[illegible] AND PHYSICAL PROPERTIE[illegible]

	Feet	Years	Inches	Millimetres		Per cent	Per cent			Pounds	Pounds	1,000 pounds	[illegible]	Inch pounds	Inch pounds	Pounds
A	[illegible]		[illegible]	4.10	11.1	36	30.7	0.460	0.515	4,525	7,692	1,548	[illegible]	6.7	18.8	8,990
					12.3	39	29.4	0.433	0.474	4,780	7,710	1,742	[illegible]	6.1	18.7	8,357
	[illegible]	[illegible]	[illegible]	4.43	12.4	38	30.6	0.435	0.503	4,695	7,556	1,700	[illegible]	6.7	16.5	9,117
					[illegible]	37	31.1	0.433	0.464	5,115	7,723	1,680	[illegible]	6.7	18.3	8,478
	[illegible]	[illegible]	[illegible]	4.58	12.2	37	29.5	0.427	0.475	4,964	7,427	1,623	[illegible]	6.4	15.4	8,981
					12.2	33	28.5	0.426	0.491	5,105	7,894	1,645	[illegible]	6.6	16.0	8,488
	34	162	25.5	4.82	12.4	33	27.9	0.420	0.474	4,987	7,534	1,605	[illegible]	6.8	15.4	8,246
					13.0	36	29.9	0.415	0.462	4,973	7,625	1,657	[illegible]	[illegible]	14.5	8,003
	42	160	25.0	5.06	12.6	31	31.7	0.409	0.436	5,071	7,432	1,610	[illegible]	[illegible]	12.8	8,248
					12.6	32	33.2	0.406	0.434	4,767	7,453	1,615	[illegible]	6.4	12.8	7,998
M	[illegible]	[illegible]	24.0	4.92	12.9	31	31.8	0.405	0.455	4,874	7,600	1,663	[illegible]	6.6	15.0	8,192
N					13.6	29	35.5	0.401	0.458	4,999	7,610	1,620	[illegible]	[illegible]	14.7	8,560
	[illegible]	[illegible]	24.0	5.01	14.0	31	37.2	0.400	0.434	4,944	7,455	1,617	[illegible]	7.5	13.7	8,133
					14.1	31	33.8	0.396	0.433	4,932	7,445	1,540	[illegible]	7.5	14.5	8,303
	[illegible]	[illegible]	[illegible]	4.75	14.3	31	31.6	0.396	0.457	4,888	7,371	1,549	[illegible]	6.6	11.6	7,920
Q					15.0	29	32.8	0.392	0.430	4,535	7,503	1,586	[illegible]	7.4	12.8	8,703
R	74	151	23.0	4.74	14.8	28	34.2	0.393	0.430	4,297	7,289	1,524	[illegible]	7.0	9.5	8,255
					13.6	27	30.5	0.391	0.442	4,363	7,041	1,528	[illegible]	6.2	10.7	8,090
T	82	147	21.5	4.71	14.1	28	27.9	0.394	0.430	4,353	7,108	1,511	[illegible]	7.1	11.1	7,740
					15.1	28	36.4	0.389	0.433	4,340	6,940	1,495	[illegible]	6.3	10.4	8,608
W	90	143	21.0	4.57	14.3	26	33.7	0.388	0.448	[illegible]	6,995	1,482	[illegible]	7.3	11.0	7,254
X					14.6	24	34.4	0.385	0.436	4,279	6,794	1,471	[illegible]	6.6	10.0	8,123
Y	98	141	20.8	4.32	14.8	25	[illegible]	0.386	0.431	4,119	6,541	1,407	[illegible]	5.4	8.9	7,710
					14.3	24	31.8	0.389	0.417	4,201	6,903	[illegible]	[illegible]	6.9	8.8	7,965
Z	106	134	20.0	4.56	12.9	23	31.3	0.398	[illegible]	4,361	6,969	1,294	[illegible]	6.8	11.1	7,288
A'					13.4	23	33.5	0.398	0.442	4,613	7,179	1,458	[illegible]	6.3	12.0	7,456
B'	114	125	19.0	4.06												
C'					13.8	24	[illegible]	0.388	0.444	3,905	6,180	1,363	[illegible]	5.9	10.2	8,170
D'	122	117	18.0	4.54	14.5	24	43.7	0.385	0.436	3,731	6,456	[illegible]	[illegible]	6.2	8.4	7,706
E'					13.0	24	34.2	0.389	0.435	3,678	6,405	1,341	[illegible]	5.4	8.5	7,906
F'	130	112	17.0	4.43	13.2	23	35.0	0.384	0.454	3,653	6,400	1,317	[illegible]	5.9	8.0	7,368
G'					13.9	[illegible]	34.6	0.385	0.425	3,847	6,334	1,234	[illegible]	5.6	8.5	7,764
H'	138	105	15.5	4.04	14.6	24	40.2	0.380	0.424	3,883	6,352	1,275	[illegible]	5.3	8.4	7,694
I'					14.4	24	40.8	0.377	0.408	[illegible]	6,087	[illegible]	[illegible]	5.0	7.8	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]
Averages				**4.44**	**14.5**	**28**	**33.5**	**0.400**	**0.444**	**4,460**	**7,090**	**1,480**	**0.7**	**6.5**	**12.1**	**8,020**

Note. Figures given for height from ground, age, average [illegible]

GREATEST VARIATIONS OF BO[illegible] AVERAGES FROM TREE AVERA[illegible]

[illegible] bolt average from tree average, per cent	26.1	−17.8	+39.[illegible]	+30.4	+15.[illegible]	+16.0	−18.1	−14.0	−21.6	[illegible]	−29.2	+55.4	−22.3
[illegible] stick average from bolt average, per cent	−81.1	+80.3	[illegible]	+162.[illegible]	[illegible]	....	−36.9	−23.4	27.0	[illegible]	−4[illegible]	[illegible]	

...PERTIES THROUGHOUT THE LENGTH OF A TYPE ...

...POLES COMPRISING THE ENTIRE ...

Fiber stress at elastic limit, per square inch	Modulus of elasticity, per square inch	Work in bending to elastic limit, per cubic inch of specimen	Height of drop of 50-lb. hammer causing ... of specimen	Compressive strength at elastic limit, per square inch	Crushing strength at maximum load, per square inch	[illegible], per square inch	Compression perpendicular to grain	Load required to embed a 0.444-inch sphere of steel to one-half its diameter: Radial surface	Tangential surface	End surface	Shearing strength per square inch, the plane of failure being: Radial	Tangential	Splitting strength per inch of width of specimen 2 inches long, the plane of failure being: Radial	Tangential	Tensile strength per square inch, the plane of failure being: Radial	Tangential	[illegible]	[illegible]	[illegible]
Pounds	1,000 pounds.	Inch pounds.	Inches	Pounds	Pounds	Pounds	Pounds		Pounds	Pounds.	Pounds	Pounds	Pounds.	Pounds	Pounds.	Pounds	Per cent	[illegible]	[illegible]
8,990	1,825	2.48	21	2,712	3,857	1,703	627	408	560	574	952	961	199	217	452	465	11.0	4.[illegible]	[illegible]
8,357	1,667	2.40	22	2,757	3,846	1,913		418	429	516	943	850	189	204	366	401	10.4	3.9	[illegible]
9,117	1,787	2.60	23	2,843	3,881	1,934		441	419	552	677	869	182	186	373	398	11.3	4.[illegible]	[illegible]
8,478	1,797	2.23	18	3,013	3,926	1,855	438	403	396	535	752	750	178	167	329	395	[illegible]	3.6	[illegible]
8,981	1,737	2.60	20	2,893	3,862	1,876	507	413	4[illegible]	509	751	734	181	164	387	396	1[illegible]		
8,488	1,798	2.25	18	3,201	3,940	1,833	585	443	468	561	774	763	192	184	280	313	1[illegible]	[illegible]	
8,246	1,619	2.34	16	3,356	3,990	1,822	501	438	445	552	813	805	193	189	329	296	12.5	[illegible]	
8,003	1,832	1.94	15	2,929	3,694	1,851	437	417	405	531	826	80[illegible]	194	168	303	400	11.2	4	
8,248	1,725	2.22	18	2,587	3,630	1,747	427	389	390	505	742		198	195	305	379	11		
7,998	1,740	2.06	19	2,726	3,706	1,760	448	388	397	507	730	[illegible]	186	187	246	395	[illegible]	[illegible]	
8,192	1,843	2.05	18	3,022	3,651	1,813	406	409	392	502	770	81[illegible]	196	166	389	321	11.[illegible]	[illegible]	
8,560	1,675	2.43	14	2,830	3,650	1,7[illegible]	360	390	403	474	829	835	184	197	332	336	12.4		
8,133	1,758	2.10	15	2,808	3,638	1,682	464	399	384	499	879	870	173	198	335	256	11.9	4.5	8.4
8,303	1,682	2.45	18	2,775	3,624	1,634	469	375	409	482	827	878	186	206	352	352	11.7	4.7	8.0
7,920	1,822	1.91	18	2,906	3,608	[illegible]711	462	376	390	486	861	850	202	181	358	327	12.3	4	
8,703	1,696	2.49	15	2,661	3,700	1,653	484	405	424	484	913	875	171	198	343	296	10.6	4.[illegible]	
8,255	1,714	2.24	18	2,945	3,736	1,661	430	393	433	479	874	896	179	182	331	415	10.7	4	
8,090	1,745	2.12	17	2,871	3,603	1,630	410	405	419	490	868	897	167	183	312	412	10.[illegible]	4	[illegible]
7,740	1,777	1.93	17	3,053	3,642	1,674	427	401	417	499	860	880	172	217	370	446	10.7	4	[illegible]
8,608	1,882	2.23	18	2,836	3,625	1,570	483	396	428	471	866	865	185	161	285	386	11.0	4.1	7.4
7,254	1,867	1.59	16	3,158	3,587	[illegible]615	407	393	422	476	843	859	183	179	352	363	11.3	4.1	[illegible]
8,123	1,896	1.97	17	2,809	3,534	[illegible]552	418	380	415	468	769	892	185	152	355	340	11.1	4.[illegible]	[illegible]
7,710	1,778	1.86	16	2,881	3,490	[illegible]75	469	344	400	420	844	864	189	174	344	343	10.6	4.[illegible]	[illegible]
7,965	1,647	2.16	14	2,709	3,431	[illegible]582	457	377	407	406	809		175	180	292	367	10.5	[illegible]	[illegible]
7,288	1,653	1.80	15	2,606	3,[illegible]	1,504	416	391	422	440	886	852	189	207	334	371	9.7	4.2	
7,456	1,717	1.82	14	2,[illegible]4	[illegible]	1,579	424	396	404	460	837	828	194	192	411	351	10.7	4.4	
8,170	1,621	2.31	13	2,712	3,556	1,600	438	369	404	429	886	868	214	188	294	321	10.9		
7,706	1,598	2.07	1[illegible]	2,577	[illegible]407	1,487	411	370	422	482	855	895	179	219	342	431	10.8		
7,906	1,547	2.29	1[illegible]	2,523	3,242	1,474	342	354	407	474	852	840	189	206	365	401	11.0		
7,368	1,606	1.91	1[illegible]	2,705	3,234	1,360	400	381	400	443	856	869	190	213	333	345	10.4	[illegible]	
7,764	1,515	2.23	13	2,653	3,234	1,426	405	339	394	454	857	917	167	183	357	335	10.4	[illegible]	
7,694	1,632	2.05	15	2,659	3,207	1,401	455	369	410	448	875	870	195	191	399	331	10.3	[illegible]	
[illegible]335	1,601	2.45	12	2,592	3,017	1,39[illegible]	371	371	405	463	869	836	199	214	334	303	9.8		
[illegible]	1,641	1.99	1[illegible]	2,706	3,168	1,408	49[illegible]	370	419	455	882	875	176	196	440	306	10.[illegible]		
[illegible]	1,520	1.4[illegible]	1[illegible]	2,468	3,[illegible]	1,[illegible]	41[illegible]	36[illegible]	390	490	865	870	183	204	440	41[illegible]	10.[illegible]		
[illegible]600	1,668	1.[illegible]	14	2,599	[illegible]	1,400		404	38[illegible]	486	719	866	197	185	380	40[illegible]	[illegible]		
[illegible]930	1,415	1.55	8	2,099	3,[illegible]	1,[illegible]	4[illegible]	40[illegible]	391	411	86[illegible]	806	17[illegible]	179	359	404	[illegible]		
8,020	**1,703**	**2.13**	**16**	**2,790**	**3,5[illegible]**	**1,620**	**446**	**394**	**415**	**487**	**834**	**850**	**186**	**190**	**350**	**371**	**11.0**	**4.4**	**7.4**

...L AVERAGES, AND OF STICK AVERAGES FROM ... AVERAGES PER CENT

[illegible]22.4	−16.9	−33.3	−50.0	−24.8	1[illegible]	+19.4	+40.6	+28.2	+34.9	+17.9	−18.8	−13.6	−5.1	−20.0	−29.7	−31.0	13.6	[illegible]	[illegible]

Otl
teristics
"P
Forest
Pls. III
"F
and St
Bulletin
"D
United
Frothin
"T
Forest
Pls. VI
"S
Agricul
4. Wa
"S
Preserv
286. I
1915.
"T
Untrea
Physic
Engine
Figs. 1
"
Oregon
perties
Associa
Figs. 7
"
O. P.
Pp. 27
"
Canad
3. Ta
"
States
R. C.

TABLE 11.—VARIATION OF MECHANICAL AND PHYSICAL PROPER

AVERAGES FOR THE LAST 88 YEARS' GROWTH IN SUCCESSI

[illegible]	Static bending: Fiber stress at elastic limit per square inch	Modulus of rupture per square inch	Modulus of elasticity per square inch	Work in bending per cubic inch of specimen: To elastic limit	To maximum load	Total	Impact: [illegible] per square inch	Modulus of elasticity per square inch
	Pounds	Pounds	1,000 pounds	Inch-pounds	Inch-pounds	Inch-pounds	Pounds	1,000 pounds
[illegible]	5 970	[illegible]	[illegible]	[illegible]	7.4		[illegible] 685	[illegible]
[illegible]	4 962	7 517	1 756	0.78	8.2		[illegible] 595	1,86[illegible]
[illegible]	4 993	7 008	1 789	0.78	8.7		[illegible] 250	1 941
[illegible]	5 583	[illegible] 898	1 700	0.95	5.7		9 255	1 907
[illegible]	5 498	8 410	1 772	0.95	7.4		9 150	1 906
[illegible]	5 504	8 137	1 72[illegible]	0.9[illegible]	6.6		8 825	1 737
[illegible]	5 15[illegible]	7 872	1 718	0.87	8.7		8 050	1,534
[illegible]	4 994	7 771	1 687	0.88	6.9		8 145	1 887
[illegible]	5 495	7 859	1 653	1.00	[illegible]		[illegible]	1 920
[illegible]	[illegible]	8 010	1,691	1.00	7.4		[illegible] 380	1 900
[illegible]	4 841	[illegible] 506	1 683	[illegible]	6.5		8 388	1 900
[illegible]	[illegible] 332	7 778	1,655	0.96	7.3			
[illegible]	5 5[illegible]	7 890	1.686	[illegible]	8.8		8 870	1 82[illegible]
[illegible]	5 [illegible]	8 042	1.623	[illegible]	[illegible]		7 045	1 88[illegible]
[illegible]	5 44[illegible]	[illegible]	[illegible]	[illegible]	6.3		[illegible] 920	1 82[illegible]
[illegible]	[illegible] 925	[illegible]	[illegible]	0.84	[illegible]		8 433	1 685
[illegible]	4 22[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible] 810	1 768
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 80	7.4		[illegible] 350	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
Averages	4 630	7 250	1 504	0.80	6.5		8 140	1 744

AL PROPERTIES THROUGHOUT THE LENGTH OF A TYPICA[illegible] TREE OF CO[illegible] [illegible]GLAS FIR

SUCCESSIVE FOUR FOOT BOLTS COMPRISING THE ENTIR[illegible] MERCHANTA[illegible] [illegible]NGTH

[illegible]	Impact Bending: Modulus of elasticity, per square inch	Impact Bending: Work in bending to elastic limit per cubic inch of specimen	Impact Bending: Height of drop of 50-lb hammer causing complete failure of specimen	Compression parallel to grain: [illegible] stress at elastic limit per square inch	Compression parallel to grain: [illegible] per square inch	Compression parallel to grain: Modulus of elasticity per square inch	Compression perpendicular to grain: Compressive stress at elastic limit, per square inch	Hardness: [illegible]	Hardness: [illegible]	Shearing parallel to grain: Shearing strength per square inch, the plane at right angles: Radial	Shearing: Tangential	Cleavage: Splitting strength per inch of width of specimen 2 inches long, the plane of failure being: Radial	Cleavage: Tangential	Tension perpendicular to grain: Radial	Tension: Tangential	Shrinkage: Volumetric [illegible]	Shrinkage: Radial	Shrinkage: Tangential
	1,000 pounds	Inch pounds	Inches	[illegible]	Pounds	1,000 pounds	Pounds	[illegible]	Pounds	Pounds		Pounds		[illegible]		Per cent	Per cent	Per cent
5	1,784	2.93	19	3,000	3,956	1,8[illegible]	702	[illegible]	606									
5	1,865	2.24	24	3,210	4,284	1,88[illegible]		[illegible]	509	976		222		[illegible]				
0	1,941	2.47	24	2,879	4,[illegible]	2,[illegible]		[illegible]	[illegible]25	856		203		[illegible]				
5	1,997	2.39	22	3,149	4,072	1,744	55[illegible]	[illegible]	[illegible]	775		188		[illegible]				
0	1,906	2.43	22	3,260	4,246	1,959	437	[illegible]	48[illegible]									
5	1,737	2.51	19	3,574	4,420	1,945	[illegible]	[illegible]	[illegible]									
0	1,534	2.36	17	3,615	4,416	1,970	[illegible]	[illegible]	[illegible]									
5	1,887	1.96	15	3,143	3,999	2,005	[illegible]	[illegible]	[illegible]	826		188		[illegible]				
5	1,929	2.21	21	3,024	4,008	2,000	[illegible]	[illegible]	[illegible]									
0	1,990	1.96	24	3,097	4,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]									
8	1,900	2.08	21	3,026	3,992	1,954	563	[illegible]	[illegible]									
				3,020	[illegible]	1,8[illegible]	[illegible]	[illegible]	[illegible]	841		[illegible]		[illegible]				
0	1,822	2.40	18	3,020	3,774	1,856	504	[illegible]	471									
5	1,888	1.46	20	2,785	[illegible]	1,745	[illegible]	[illegible]	[illegible]	849		200		[illegible]				
0	1,822	1.91	18	2,949	3,819	1,74[illegible]	53[illegible]	[illegible]	590	863		196		[illegible]				
5	1,685	2.36	14	2,800	[illegible]	1,[illegible]		[illegible]	507									
0	1,768	[illegible]	[illegible]	[illegible]	[illegible]	1,845	437	441	490	[illegible]				[illegible]				
0	1,737	[illegible]	[illegible]	3,068	3,849	1,708	448	[illegible]	488	[illegible]		175		364				
[illegible]	[illegible]	[illegible]	17	3,158	[illegible]	[illegible]	458	[illegible]	507	[illegible]		182		[illegible]				
8	1,882	[illegible]	18	[illegible]	[illegible]	1,690	436	[illegible]	479	[illegible]		168		[illegible]				
4	1,847	1.59	16	3,386	[illegible]	[illegible]	400	[illegible]	484	865		184		[illegible]				
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	845		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]									
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	15	[illegible]	3,200	1,40[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	1.42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,400		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]				
0	1,744	2.14	17	2,940	3,730	1,693	497	433	504	859		194		380				

TABLE 11.—VARIATIO

Bolt No.	Height from ground—feet.	Age—years.	Average Diameter inches.	Average Fibre Length—Millimeters. Annual Ring Designation 9	8	7	6	5	4	3	2	1	0	Rings per Inch. Stick Numbers 1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1
Stump	2	177	30·8	1·15	2·99	3·13	3·67	3·61	4·6[illegible]	3·66	3·20	3·25	3·56							
A. and B.	10	172	31·3	1·29	3·52	4·38	3·97	4·76	4·[illegible]	4·23	4·71	4·41	4·98	5·8	8·0	10·9	12·3	14·6	[illegible]	
C														5·5	8·9	12·3	15·6	16·3	11·0	
D	18	168	27·5	1·19	3·07	4·33	5·26	4·68	5·19	5·45	5·04	5·29	4·84	5·5	8·0	11·5	15·8	18·0	17·0	
E														5·0	6·7	11·1	16·0	17·2	20·0	
F	26	165	27·0	1·09	2·57	4·10	5·12	5·11	5·[illegible]	5·50	5·25	5·70	5·97	4·8	7·3	13·3	17·0	15·3	2[illegible]	
G														4·8	6·8	14·0	17·3	16·8		
H	34	162	25·5	0·91	2·66	4·50	5·26	5·34	5·60	5·85	6·05	6·02	6·01	4·5	7·6	14·3	17·8	15·8		
I														4·7	7·9	14·1	18·1	17·3		
J	42	160	25·0		1·28	4·15	4·99	5·42	6·[illegible]	5·78	5·87	5·94	6·07	4·3	7·9	13·5	18·3	17·0		
K														4·0	7·1	13·6	18·1	20·3		
L	50	158	24·0		1·11	4·42	5·06	5·06	5·[illegible]	5·80	5·55	5·92	6·09	4·0	7·8	14·1	18·6	18·3		
M														4·0	9·1	14·3	19·8	20·0		
N	58	154	24·0		1·29	4·49	4·81	5·75	5·60	6·04	5·56	5·82	5·35	4·7	9·6	14·8	20·9	20·7		
O														4·7	9·5	15·9	19·9	19·0		
P	66	153	23·5		0·91	3·85	5·02	5·20	5·2[illegible]	5·91	5·54	5·56	5·61	4·8	10·1	15·8	18·5	18·[illegible]		
Q														5·3	9·5	16·8	21·3	22·0		
R	74	151	23·0		1·07	3·43	5·15	5·07	5·[illegible]	5·84	5·73	5·55	5·56	5·7	9·8	17·3	20·7	22·0		
S														5·5	9·1	16·8	20·0			
T	82	147	21·5		1·12	3·30	4·89	4·80	5·[illegible]	6·08	5·66	5·31	5·91	6·0	10·5	18·0	17·8			
U														6·5	9·9	18·0	20·8	24·0		
V	90	143	21·6		0·92	2·27	4·69	5·38	5·[illegible]	5·62	5·49	5·69	5·79	6·8	10·4	17·5	20·3			
W														7·5	11·1	17·0	20·7			
X	98	141	20·8		1·08	1·20	4·18	4·14	5·1[illegible]	5·23	6·17	5·52	6·31	8·0	11·0	16·4	22·5			
Y														9·3	11·1	15·3	19·0			
Z	106	134	20·0			1·06	3·18	4·46	5·[illegible]	5·43	5·17	6·03	6·11	8·5	9·5	15·4	21·3			
A'														9·0	9·9	17·0	17·5			
B'	114	125	19·0			0·90	1·95	4·11	4[illegible]	5·22	4·90	5·32	5·36							
C'														8·3	10·0	16·9	19·3			
D'	122	117	18·0				0·94	4·03	4·7[illegible]	5·11	5·56	5·81	5·66	7·5	10·5	17·3	20·3			
E'														8·0	10·9	16·5				
F'	130	112	17·0				0·87	2·89	4·6[illegible]	5·08		5·88	5·92	8·3	10·9	18·1				
G'														8·5	11·8	18·9				
H'	138	105	15·5				1·04	2·30	4·5[illegible]	5·13	5·20	5·05	5·08	9·0	12·5	18·9				
I'														10·3	12·1	18·8				
J'	146	97	14·5					1·00	3·7	5·00	5·14	4·87	4·21	9·7	13·3	19·7				
K'														10·3	14·0					
L'	154	88	11·5					0·99	2·7[illegible]	4·37	4·96	5·07	5·17	10·3	15·0					
M'														11·3	15·6					
Averages				1·13	1·81	3·30	3·89	4·20	4·97	5·32	5·32	5·40	5·48	6·8	10·0	15·7	18·8	18·5	16·6	

NOTE:—Test sticks are numbered from the pith towards the periphery of the tree in accordance with the scheme shown in Fig. 42 (Appendix). All sticks of the same odd, and next higher even [illegible]
Annual ring designation numbers [illegible] successive periods of 20 years in the growth of the tree, No. 0 being the last annual ring at the periphery. The measurement farthest from the perip[illegible]
Figures given for height from ground, age, average diameter, and fibre length, refer to the [illegible] of the bolt indicated.

VARIATION OF MECHANICAL AND PHYSICAL PROPERTIES FROM THE PITH TO THE PERIPHERY OF A TYPICAL TREE OF COAST DOUGLAS FIR. AVERAGES [illegible] TEST STICKS AT INT[illegible]

	Summer-wood—per cent. Stick Numbers.						Moisture Content based on weight [illegible] wood oven dry—per cent. Stick Numbers.						Specific Gravity, oven dry, based on volume when tested. Stick Numbers.						Static Bending Fibre Stress [illegible] Elastic Limit Pounds per [illegible] Stick Numbers				
11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10
[illegible]	23	35	38	37	35	41	31·3	30·0	29·4	30·2	30·9	52·9	0·356	0·412	0·468	0·464	0·484	0·530		[illegible]	5,320	4,633	[illegible]
11·0	37	42	38	39	41	38	30·4	30·7	28·6	28·6	29·5	29·4	0·359	0·407	0·441	0·448	0·465	0·509		[illegible]	4,790	4,944	[illegible]
17·0	40	36	37	33	39	44	29·3	29·7	28·8	28·8	30·4	52·4	0·365	0·421	0·446	0·441	0·456	0·492	3,620	4,305	4,832	4,911	[illegible]
20·0	31	35	39	37	38	44	28·9	29·1	28·5	28·1	27·9	74·0	0·369	0·408	0·445	0·445	0·463	0·475		4,595	4,071	5,330	[illegible]
[illegible]	33	35	36	39	43	40	28·2	28·4	28·0	27·8	27·7	77·5	0·361	0·415	0·433	0·436	0·467	0·456	3,640	[illegible]	5,283	5,237	[illegible]
	19	38	33	34	36		28·2	27·9	27·2	26·7	36·2		0·363	0·418	0·437	0·432	0·468			4,459	5,460	5,345	[illegible]
	21	35	33	35	38		28·4	28·6	27·2	26·9	29·3		0·348	0·412	0·433	0·428	0·463		3,710	[illegible]	5,303	5,271	[illegible]
	22	35	37	38	41		30·1	29·6	28·8	28·6	35·4		0·344	0·402	0·426	0·418	0·447			[illegible]	4,982	[illegible]	[illegible]
	20	32	33	33	35		30·7	30·4	29·4	30·3	42·4		0·346	0·399	0·426	0·416	0·446		3,200	4,200	5,443	5,305	[illegible]
	22	32	32	33	37		31·1	30·2	29·3	29·1	56·3		0·346	0·398	0·421	0·417	0·441		3,210	3,745	4,658	5,142	[illegible]
	23	29	30	35	38		30·2	30·1	28·7	30·5	44·8		0·346	0·396	0·420	0·412	0·435			4,265	5,071	4,657	[illegible]
	18	27	34	32	33		29·7	28·7	28·6	41·4	64·7		0·351	0·398	0·412	0·414	0·418			4,315	4,927	5,307	[illegible]
	19	28	31	34	41		29·6	29·2	28·7	44·0	71·2		0·353	0·396	0·412	0·409	0·404			3,975	4,936	5,150	[illegible]
	21	30	31	34	36		29·8	32·0	28·7	44·6	46·9		0·354	0·383	0·405	0·409	0·424			[illegible]	4,944	5,127	[illegible]
	21	29	33	38	34		30·0	29·7	29·2	32·0	50·6		0·351	0·396	0·399	0·419	0·406			4,480	4,633	5,118	[illegible]
	18	26	30	35	35		27·4	27·4	26·9	39·1	63·7		0·349	0·392	0·395	0·403	0·402			3,200	4,590	4,925	
	17	26	28	32	34		26·9	27·1	27·1	47·4	78·4		0·350	0·391	0·396	0·407	0·414			4,213	4,407	4,220	
	19	25	28	32			27·8	27·6	27·2	40·2			0·357	0·390	0·395	0·409				3,867	4,440	5,030	
	20	26	30	32			27·6	27·9	27·1	29·7			0·365	0·389	0·393	0·419				4,073	4,240	5,025	
	21	25	32	33	34		29·8	29·0	28·0	53·5	61·9		0·360	0·385	0·395	0·398	0·420			3,694	4,072	5,158	[illegible]
	18	23	29	30			28·7	28·7	28·6	50·7			0·361	0·384	0·395	0·403				3,670	4,203	4,747	
	17	21	26	28			28·5	29·6	27·9	53·6			0·361	0·377	0·395	0·397				3,945	4,040	4,740	
	17	22	27	30			28·3	28·5	27·6	44·6			0·358	0·379	0·396	0·398				3,975	3,894	4,440	
	18	24	26	29			28·6	28·2	27·9	52·6			0·366	0·381	0·402	0·405				4,242	4,159		
	19	22	25	28			28·1	28·3	29·0	50·1			0·398	0·395	0·400	0·405				[illegible]	4,184	4,200	
	18	23	23	28			28·5	28·7	38·2	38·7			0·385	0·400	0·395	0·412			4,157	4,463	4,725	5,146	
	18	23	25	27			29·6	29·2	38·3	66·4			0·367	0·393	0·392	0·388				3,700	3,958	3,945	
	19	25	23	27			29·9	29·5	43·5	79·4			0·379	0·396	0·381	0·374			3,640	3,667	3,805	3,725	
	21	24	24				30·6	29·6	39·7				0·372	0·397	0·385					3,685	3,675		
	19	25	24				29·7	29·5	44·4				0·377	0·392	0·380					3,690	3,640		
	20	23	24				29·0	28·4	43·7				0·381	0·396	0·374					3,900	3,645		
	20	24	25				28·7	28·5	56·1				0·381	0·394	0·367					4,160	3,693		
	21	25	24				28·5	28·5	59·2				0·391	0·390	0·360					3,610	4,158		
	21	24	22				27·8	28·3	84·7				0·387	0·388	0·349					4,485	3,300		
	21	24					29·0	31·7					0·394	0·383					4,200	[illegible]			
	22	24					29·8	36·8					0·401	0·391						[illegible]			
	20	25					29·2	35·1					0·394	0·385									
16·6	21	28	30	33	37	41	29·1	29·5	33·9	40·1	46·0	53·2	0·366	0·395	0·405	0·415	0·440	0·492	3,670	4,110	4,480	4,890	5,330

igher even number being at the same distance from the pith.
m the periphery is in every case for the first annual ring next the pith regardless of whether this happens to be an even number of double-decades from the periphery or not

DOUGLAS FIR. AVERAGES FOR [illegible] STICKS AT INTERVALS OF 2½ INCHES FROM THE PITH FOR SU[illegible]CESSIVE FOUR-FOOT BOLTS COMPRISING THE ENTIRE MERCHANTABL

…n volume when tested.			Static Bending Fibre Stress at Elastic Limit—Pounds per Sq. Inch.						Static Bending Modulus of Rupture—Pounds per Sq. Inch.						Static Bending Modulus of Elasticity—1,000 lbs. per Sq. Inch.						S… Work to Elastic L…		
			Stick Numbers.						Stick Numbers.						Stick Numbers.						S…		
…	9 and 10	11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1 and 2	3 and 4	5 …
…4	0·484	0·530		3,800	5,320	4,633	4,657	3,740		6,275	8,145	8,000	7,795	7,353		1,349	1,642	1,713	1,553	1,373		0·61	0
…8	0·465	0·509		4,094	4,790	4,944	5,198	4,725		7,188	8,097	7,654	7,973	7,220		1,663	1,764	1,714	1,797	1,714		0·56	0
…1	0·456	0·492	3,620	4,305	4,832	4,911	4,813	5,172	6,260	6,943	7,864	7,739	7,795	8,020	1,376	1,618	1,807	1,663	1,760	1,817	0·53	0·64	0
…5	0·463	0·475		4,593	4,971	5,330	5,515	5,250		7,250	7,598	7,968	7,720	8,075		1,589	1,709	1,688	1,706	1,711		0·74	0
…6	0·467	0·456	3,640	4,438	5,283	5,237	5,498		5,690	6,805	7,740	7,680	8,410		1,200	1,552	1,700	1,648	1,772		0·61	0·71	0
…2	0·468			4,459	5,460	5,345	5,263			7,318	8,380	7,854	8,420			1,529	1,693	1,653	1,789			0·73	0
…8	0·463		3,710	4,908	5,303	5,271	5,040		6,070	7,317	8,006	7,644	8,100		1,172	1,511	1,744	1,654	1,782		0·65	0·89	0
…8	0·447			4,265	4,982	5,263	4,725			6,880	7,699	7,521	8,020			1,490	1,676	1,634	1,740			0·68	0
…6	0·446		3,200	4,200	5,443	5,305	5,545		5,730	6,780	7,710	7,497	8,220		…200	1,524	1,704	1,621	1,684		0·47	0·65	0
…7	0·441		3,210	3,743	4,658	5,142	5,850		5,760	6,639	7,400	7,883	8,148		…226	1,533	1,639	1,668	1,713		0·47	0·52	0
…2	0·435			4,265	5,071	4,657	5,025			6,690	7,774	7,545	7,647			1,600	1,666	1,648	1,717			0·63	0
…4	0·418			4,315	4,927	5,307	5,356			7,025	7,870	7,670	7,760			1,512	1,648	1,642	1,667			0·69	0
…9	0·404			3,975	4,936	5,150	5,890			6,950	7,485	7,460	8,320			1,547	1,568	1,669	1,703			0·57	0
…0	0·424			4,672	4,944	5,127	5,356			6,988	7,420	7,803	8,280			1,458	1,561	1,588	1,658			0·83	0
…9	0·406			4,480	4,633	5,1[illegible]5	5,780			6,820	7,310	7,650	7,820			1,386	1,527	1,652	1,633			0·81	0
…3	0·402			3,200	4,590	4,[illegible]25				6,890	7,507	7,703				1,602	1,566	1,601				0·35	0
…7	0·414			4,213	4,407	4,220				7,278	7,233	7,490				1,508	1,556	1,474				0·66	0
…9				3,867	4,440	5,030				6,683	7,195	7,425				1,479	1,517	1,613				0·57	0
…				4,073	4,240	5,025				6,840	7,090	7,660				1,483	1,454	1,623				0·63	0
…8	0·420			3,694	4,072	5,158	5,720			6,727	6,853	7,280	7,250			1,431	1,477	1,614	1,517			0·53	0
…3				3,670	4,203	4,747				6,690	6,968	7,133				1,482	1,455	1,518				0·51	0
…7				3,945	4,040	4,740				6,475	6,987	6,813				1,430	1,521	1,447				0·61	0
…8				3,975	3,894	4,440				6,480	6,880	6,242				1,355	1,460	1,388				0·65	0
…5				4,242	4,159					7,000	6,805					1,352	1,268					0·74	0
…5				4,707	4,184	4,200				7,250	6,830	6,822				1,304	1,309	1,230				0·96	0
			4,157	4,463	4,725	5,146			6,576	7,420	6,994	7,670			1,337	1,475	1,500	1,460			0·72	0·75	0
				3,760	3,958	3,945				5,300	6,313	6,830				1,359	1,313	1,469				0·58	0
…4			3,640	3,667	3,805	3,725			6,620	6,360	6,540	6,350			…297	1,301	1,332	1,358			0·57	0·58	0
				3,685	3,675					6,540	6,338					1,365	1,330					0·55	0
				3,690	3,640					6,380	6,407					1,325	1,314					0·58	0
				3,966	3,645					6,355	6,303					1,188	1,304					0·75	0
				4,169	3,693					6,658	6,315					1,311	1,252					0·74	0
				3,616	4,158					6,179	5,950					1,251	1,221					0·58	0
				4,485	…300					6,869	5,338					1,196	1,051					0·94	0
			4,200	4,180					6,880	6,702					…558	1,238					0·72	0·79	
				4,200						6,537						1,295						0·76	
…15	0·440	0·492	3,670	4,110	4,480	4,890	5,330	4,720	6,200	6,760	7,160	7,440	7,980	7,670	1,271	1,433	1,507	1,580	1,700	1,654	0·59	0·67	0

…eriphery or not.

HANTABLE LENGTH OF THE TREE.

Static Bending to Elastic Limit—Inch lbs. per Cu. Inch.					Static Bending Work to Max. Load—Inch lbs. per Cu. Inch.						Static Bending Total Work—Inch lbs. per Cu. Inch.						Compression Parallel to Grain Crushing Strength at Max. Load—Lbs. per Sq. Inch.					
Stick Numbers.					Stick Numbers.						Stick Numbers.						Stick Numbers.					
3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12
0·61	0·97	0·70	0·78	0·58		5·9	8·0	6·5	6·6	5·0		19·9	20·5	15·2	16·5		2,688	3,392	4,175	4,103	4,143	4,212
0·56	0·73	0·80	0·84	0·72		7·0	6·7	5·6	5·8	4·5		16·0	16·4	16·8	13·8	28·0	2,760	3,406	4,055	4,203	4,270	4,298
0·64	0·72	0·81	0·73	0·82	4·5	6·3	7·3	7·3	7·3	4·1		20·8	14·0	14·3	15·1	18·5	2,946	3,566	4,111	4,008	4,328	4,318
0·74	0·81	0·93	1·00	0·90		7·9	5·9	7·4	6·8	4·5		28·4	15·3	17·0	15·0	16·0	3,086	3,429	4,093	4,133	4,252	3,891
0·71	0·92	0·93	0·95		4·5	4·8	6·7	7·6	7·4		9·8	17·4	12·3	14·9	22·7		2,897	3,533	4,094	4,040	4,652	3,840
0·73	0·98	0·96	0·87			4·8	8·6	7·0	6·2			16·2	17·7	13·6	19·3		2,863	3,691	4,139	4,215	4,625	
0·89	0·90	0·94	0·80		5·1	6·9	8·5	6·9	4·4			16·6	15·8	14·6	14·9		2,730	3,591	4,136	4,171	4,660	
0·68	0·83	0·94	0·72			8·4	7·6	6·3	7·4			15·5	12·2	13·8	16·6		2,662	3,417	3,942	3,833	4,165	
0·65	0·98	0·97	1·03		4·1	7·0	7·9	7·1	7·1		6·4	12·7	18·6	10·2	15·9		2,552	3,413	3,901	3,916	4,100	
0·52	0·74	0·88	1·12		3·8	5·0	6·5	6·8	7·9		9·9	11·2	10·6	14·7	17·4		2,683	3,451	3,933	4,053	4,089	
0·63	0·87	0·73	0·82			5·9	6·9	6·6	6·3			12·9	14·8	13·9	18·5		2,698	3,413	3,864	3,913	4,070	
0·69	0·83	0·95	0·96			7·0	8·8	7·4	7·2			15·8	11·9		16·3		2,888	3,510	3,853	3,909	3,895	
0·57	0·86	0·89	1·13			7·3	7·0	7·5	9·5			11·7	10·0	14·6	18·4		2,815	3,509	3,815	3,890	3,658	
0·83	0·88	0·92	0·96			7·1	6·7	8·1	9·1			12·5	12·4	17·6	15·4		2,862	3,381	3,813	3,871	4,000	
0·81	0·78	0·88	1·13			6·1	7·1	6·5	6·1			8·9	9·0	16·9			2,893	3,489	3,713	4,113	3,525	
0·35	0·75	0·84				7·2	6·7	8·1				12·3		13·2			2,970	3,591	3,828	3,871	3,818	
0·66	0·70	0·67				7·3	6·0	9·3				10·1	8·9				2,945	3,718	3,834	3,958	4,020	
0·57	0·72	0·88				4·7	7·1	7·6				11·6	8·4	12·1			2,880	3,559	3,706	3,991		
0·63	0·69	0·87				6·9	6·8	7·7				9·0	8·9	15·3			3,035	3,526	3,704	4,056		
0·53	0·63	0·92	1·20			6·6	6·7	5·9	5·4			10·0	10·7		10·4		2,987	3,508	3,745	3,879	3,810	
0·51	0·68	0·83				8·2	6·5	3·0				11·2	9·0	12·8			3,033	3,473	3,721	3,888		
0·61	0·60	0·88				5·0	8·4	5·9				7·3	10·5	12·2			3,069	3,449	3,730	3,684		
0·65	0·58	0·80				6·7	7·0	3·0				7·5	11·7	7·6			3,048	3,404	3,731	3,586		
0·74	0·76					6·2	7·6					8·8					3,004	3,271	3,681	3,704		
0·96	0·74	0·80				5·7	7·1	7·9				11·3		10·9			3,209	3,361	3,630	3,541		
0·75	0·83	1·01			6·6	7·4	5·6	5·6				9·2		14·7			3,242	3,552	3,581	3,730		
0·58	0·66	0·59				7·0	4·9	6·7				8·0	10·5	12·1			2,940	3,283	3,423	3,491		
0·58	0·61	0·57			7·0	6·4	6·2	5·7				9·7	9·5	6·1			3,057	3,379	3,355	3,131		
0·55	0·58					5·8	5·2					8·5	8·6				3,120	3,279	3,219			
0·58	0·57					5·1	6·1					8·3	9·4				3,106	3,356	3,238			
0·75	0·58					6·3	4·4					6·9	10·0				3,130	3,379	3,101			
0·74	0·61					5·7	5·0						8·4					3,311	3,088			
0·58	0·79					5·2	3·2					8·6	7·0					3,242	2,821			
0·94	0·58					6·7	3·3					9·2					3,290	3,292	2,718			
0·79					7·3	7·2						9·8					3,368	3,250				
0·76						4·6						9·2						3,219				
																	3,248	3,121				
0·67	**0·75**	**0·85**	**0·94**	**0·76**	**5·4**	**6·4**	**6·6**	**6·9**	**6·9**	**4·5**	**8·7**	**12·1**	**11·8**	**13·5**	**16·7**	**20·8**	**2,960**	**3,420**	**3,690**	**3,890**	**4,120**	**4,110**

PUBLICATIONS ISSUED BY THE FORESTRY

(Where number and title are omitted the document is out of print.)

Bulletin 1. Tree Planting on the Prairies.
" 8. Forest Products of Canada, 1908.
" 11. Forest Products of Canada, 1909; Lumber, Square Timber, Lath and Shingles
" 12. Forest Products of Canada, 1909: Pulpwood.
" 14. Forest Products of Canada, 1909; Cross-ties Purchased.
" 15. Forest Products of Canada, 1909.
(Being Bulletins 11, 12, 13, 14, 19 and 20.) French edition only.
" 16. Forest Fires and Railways.
" 22. Forest Products of Canada, 1910: Cross-ties.
" 23. Forest Products of Canada, 1910: Timber used in Mining Operations.
" 24. Wood-using Industries of Canada, 1910: Agricultural Implements and Vehicles, Furniture and Cars and Veneer.
" 27. Forest Products of Canada, 1910: Cooperage.
" 29. Timber Conditions in the Lesser Slave Lake Region.
" 32. The Turtle Mountain Forest Reserve.
" 33. Forest Conditions in the Rocky Mountains Forest Reserve.
" 34. Forest Products of Canada, 1911: Lumber, Square Timber, Lath and Shingles.
" 35. Forest Products of Canada, 1911: Poles and Cross-ties.
" 36. Wood-using Industries of Ontario.
" 37. Forest Products of Canada, 1911.
(Being Bulletins 30, 31, 34 and 35.)
" 38. Forest Products of Canada, 1912: Pulpwood.
" 39. Forest Products of Canada, 1912: Poles and Ties.
" 42. Co-operative Forest Fire Protection.
" 44. Wood-using Industries of the Maritime Provinces.
" 46. Forest Products of Canada, 1913: Pulpwood.
" 47. Forest Products of Canada, 1913: Poles and Cross-ties.
" 48. Forest Products of Canada, 1913: Lumber, Lath and Shingles.
" 49. Treated Wood-block Paving.
" 51. Game Preservation in the Rocky Mountains Forest Reserve.
" 52. Forest Products of Canada, 1913 (Being Bulletins 46, 47, and 48).
" 53. Timber Conditions in the Smoky River Valley and Grande-Prairie Country.
" 54. Forest Products of Canada, 1914: Pulpwood.
" 56. Forest Products of Canada, 1914: Lumber, Lath and Shingles.
" 57. Forest Products of Canada, 1914 (Being Bulletins 54, 55 and 56).
" 58a. Forest Products of Canada, 1915: Lumber, Lath and Shingles.
" 58b. Forest Products of Canada, 1915: Pulpwood.
" 58c. Forest Products of Canada, 1915: Poles and Cross-ties.
" 59. Canadian Woods for Structural Timbers.
" 60. Canadian Douglas Fir: Its Mechanical and Physical Properties.
" 62a. Forest Products of Canada, 1916: Lumber, Lath and Shingles.
" 62b. Forest Products of Canada, 1916: Pulpwood.
" 62c. Forest Products of Canada, 1916: Poles and Cross-ties.

Circular 5. Planning a Tree Plantation for a Prairie Homestead.
" 6. Preservative Treatment of Fence-posts.
" 7 Manitoba a Forest Province.
" 8. The Forest Products Laboratories.
" 9. Chemical Methods for Utilizing Wood Wastes.
" 11. The Relation of Forestry to the Development of the Country.